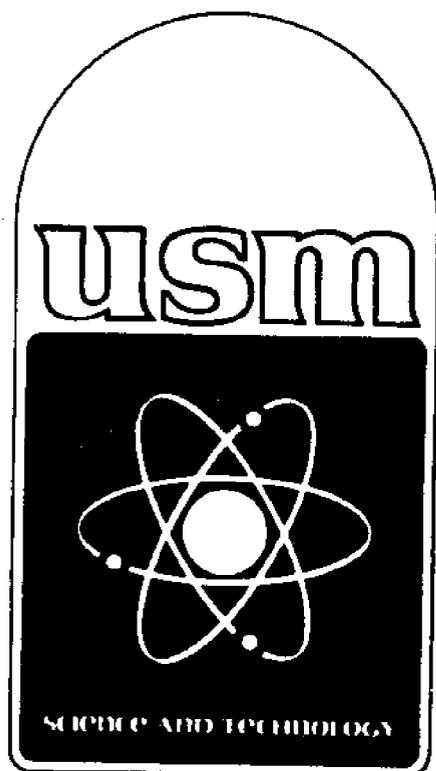


# College of Science and Technology



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PERIODICITY, IDENTIFICATION, AND CONTROL  
OF ALGAE IN MANAGED PONDS

by

Albert Nickey Fleming

University of Southern Mississippi

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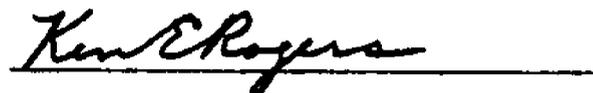
Albert Nickey Fleming

A Thesis

Submitted to the Graduate School  
of the University of Southern Mississippi  
in Partial Fulfillment of the Requirements  
for the Degree of Master of Science

Approved:

  
Director

  
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## CHAPTER I

### INTRODUCTION

Commercial and federal fish hatcheries have several problems with aquatic angiosperms and algae. Aquatic angiosperms and filamentous algae often prevent successful fish harvesting and cause fish kills due to oxygen depletion (Snow, 1964; Swingle, 1968). Blue-green algae may cause fish kills due to oxygen depletion or by algal toxins produced by the algae (Swingle, 1968). Certain species of Anabaena, Anacystis, Aphanizomenon, Coelosphaerium, Gloeotrichia, Microcystis, Nodularia, and Nostoc are known to produce algal toxins. These algal toxins have been reported in the literature to cause death in cattle, sheep, hogs, shorebirds, songbirds, chickens, ducks, cats, and dogs (Jackson, 1971).

The control of aquatic angiosperms and algae is limited by several factors at commercial and federal fish hatcheries (Lawrence, 1958; Dupree, 1960; Snow, 1964). Commercial fish hatcheries are limited primarily by cost and availability of algaecides. Snow (1964) stated that the cost of simazine was a limiting factor in its use at federal fish hatcheries. Due to federal regulations only copper sulfate may be used at federal hatcheries.

Copper sulfate is one of the most effective and widely used algaecides on the market today. However, it is not always an adequate algal control, since many algae are resistant to copper sulfate (Palmer, 1959) or fish kills may result from excessive applications (Swingle, 1968). Palmer (1959) also stated that copper sulfate is not effective in waters where the methyl orange alkalinity exceeds 50 parts per million (ppm). The copper precipitates from the water as copper carbonate.

Shell (1962) and Avault (1965), in their studies with grass carp, Ctenopharyngodon idella; common carp, Cyprinus carpio; Nile tilapia, Tilapia nilotica; the Java tilapia, T. mossambica; and the congo tilapia, T. melanopleura reported that these herbivorous were not the total answer to aquatic weed control. They found that problems concerning spawning in other than natural waters and death caused by low water temperature must be eliminated before the carp will play an important role in aquatic weed control. However, Avault (1968) stated that artificial spawning has been accomplished by the use of hormones. In most cases the herbivorous fish did not eliminate nuisance algae from the ponds tested when stocked into established populations. Chara, a frequent inhabitant of fish hatcheries, was, however, eradicated by the carp (Shell, 1962).

The objectives of this research were to:

1. Determine the various genera of algae occurring at a commercial and a federal fish hatchery.

2. Record the periodicity and abundance of each division of algae on a generic basis.

3. Photograph and describe the most common plankton algae found at the hatcheries.

4. Correlate physical, chemical, and biological data in an attempt to better understand the periodicity as well as the control of nuisance algae.

The two fish hatcheries studied were Ole Joe's Catfish Hatchery, Hattiesburg, Mississippi and the Lyman National Fish Hatchery, Lyman, Mississippi. Ole Joe's Catfish Hatchery produces channel catfish, Ictalurus punctatus, while the Lyman National Fish Hatchery produces largemouth bass, Micropterus salmoides; bluegill, Lepomis macrochirus, and channel catfish, Ictalurus punctatus.

The water supply at the commercial catfish hatchery was from a small spring-fed stream, Priests Creek. The Lyman Fish Hatchery receives water from the Biloxi River and artesian wells located at the hatchery. Both hatcheries had highly eutrophic holding ponds due to feeding, water supply, and agricultural drainage. The water from artesian wells at the federal fish hatchery was high in soluble phosphate which increased phosphate levels in ponds receiving well water.

## CHAPTER II

### MATERIALS AND METHODS

Water and plankton samples were taken every two weeks from Ole Joe's Catfish Hatchery and the Lyman National Fish Hatchery. Samples were taken from the federal fish hatchery from April, 1971 through April, 1972, and at the commercial fish hatchery from May, 1971 through April, 1972. Qualitative and quantitative analyses of phytoplankton, pH, water temperature, dissolved oxygen, calcium hardness, total hardness, nitrogen, and phosphorous values were measured. Total numbers of copepods, cladocerans, and rotifers were recorded.

Collection stations at the federal fish hatchery consisted of a largemouth bass brood pond, two channel catfish fingerling ponds, and a bass-bluegill rearing pond (Fig. 1). The channel catfish fingerling ponds were 0.5 acres in surface area. The bass-bluegill rearing pond and the largemouth bass brood pond were three acres and ten acres in surface area respectively. All ponds were from two to five feet deep with each pond constructed for independent draining and filling. The water level in individual ponds was occasionally lowered as an aid to aquatic weed control. Collections were made at drainage points to facilitate sampling.

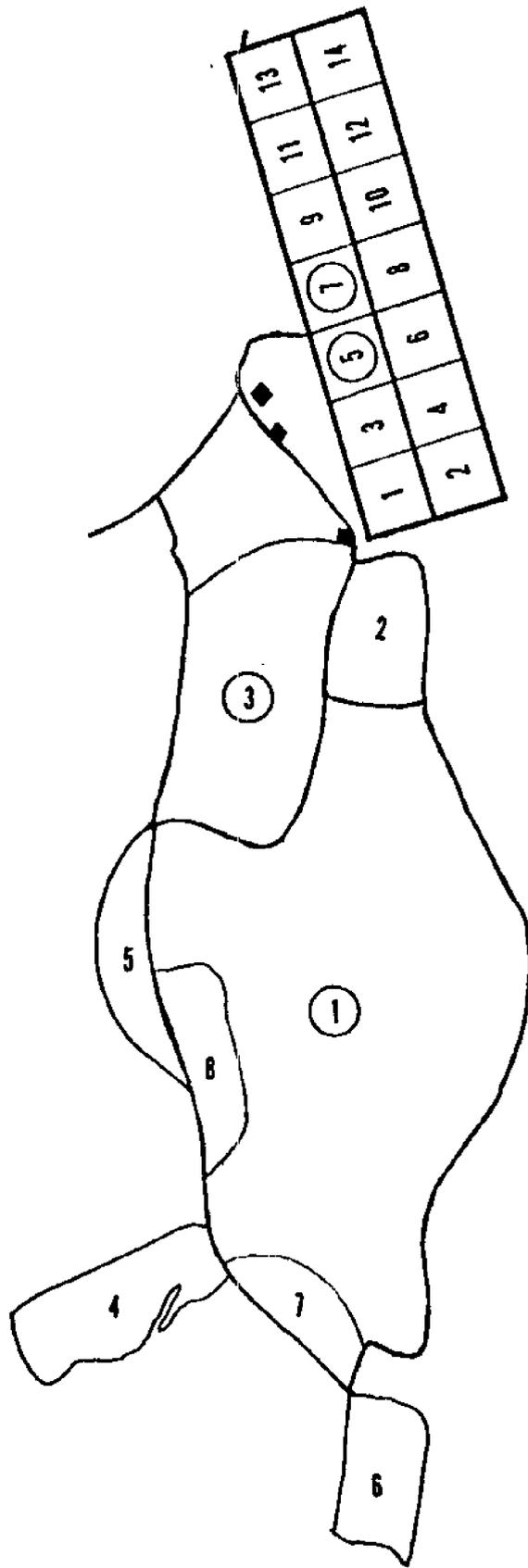


Fig. 1.--Map of the Ponds at the Lyman Hatchery  
(Circles indicate sampled ponds.)

Ole Joe's Catfish Hatchery produces channel catfish exclusively. Therefore, only ponds containing channel catfish could be sampled. A channel catfish fingerling pond, feed-out pond, and brood pond were selected as collection stations (Fig. 2). Three additional channel catfish fingerling ponds containing Chara were sampled during September, 1971; October, 1971; and April, 1972. One pond containing Nitella was sampled monthly from January, 1972 through March, 1972. All sampling at the commercial fish hatchery was conducted from a predetermined site on the pond bank.

The size of the ponds at Ole Joe's Catfish Hatchery ranged from 0.5 acres to three acres in surface area. The channel catfish brood pond and the feed-out pond were three acres in surface area; the fingerling ponds were 0.5 acres in surface area. The individual ponds sampled were constructed for independent draining and filling. The average depth varied from two to four feet. The only water source at the commercial hatchery was Priests Creek.

Water samples were obtained with Kemmerer and sewage water samplers. The water samples were taken approximately eighteen inches below the surface and transferred to 500 ml polyethylene bottles. The water samples were then placed on ice while in transit to the laboratory.

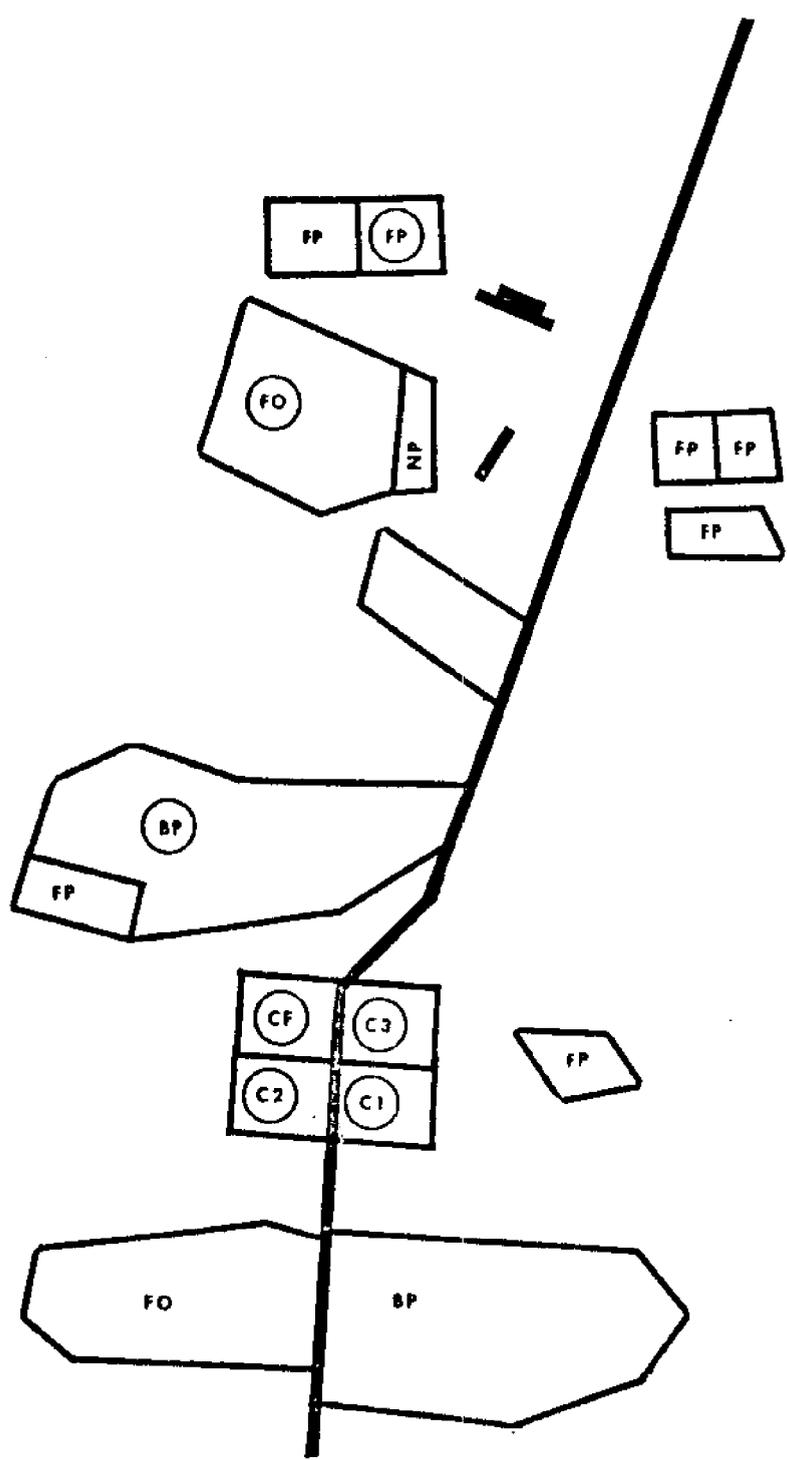


Fig. 2.--Map of the Ponds at Ole Joe's Catfish Hatchery (Circles indicate sampled ponds.)

- |         |                     |                     |
|---------|---------------------|---------------------|
| LEGEND: | FP--Fingerling Pond | C1--Chara No. 1     |
|         | BP--Brood Pond      | C2--Chara No. 2     |
|         | FO--Feed-out Pond   | C3--Chara No. 3     |
|         |                     | C4--Fingerling Pond |
|         |                     | Chara free.         |

### Temperature

The water temperature was determined by placing a centigrade thermometer directly into the sewage sampler, or into the polyethylene bottle if the Kemmerer sampler was used to obtain the water sample.

### Hardness

Calcium hardness and total hardness values were obtained in the field with a Hach hardness field testing kit. Water samples for the calcium and total hardness test were taken from the sewage water sampler or the Kemmerer water sampler with a 6 ml Hach measuring tube. Calcium hardness and total hardness values were expressed as milligrams per liter (mg/l)  $\text{CaCO}_3$  (Tables 1-7, pp. 25-31).

### pH

The pH of the water was determined in the laboratory with a Model PBL Sargent-Welch pH meter. The instrument was calibrated with standard pH buffers of seven and four before pH determinations were made.

### Dissolved Oxygen

Dissolved oxygen measurements were made in the field with a Hach dissolved oxygen field testing kit, and in the laboratory by the Winkler method for dissolved oxygen determinations (American Public Health Association, 1971). Water samples for the Hach measurements were obtained

directly from the sewage water sampler or the Kemmerer water sampler. Water samples for the Winkler dissolved oxygen measurements were obtained by placing a 300 ml biochemical oxygen demand (BOD) bottle into the sewage sampler and allowing it to fill with water. When the Kemmerer sampler was used, the BOD bottle was allowed to flush three times before the reagents were added. Dissolved oxygen values were expressed as mg/l O<sub>2</sub> (Tables 1-7, pp. 25-31).

Procedure.--Two ml of manganese sulfate were added below the surface of the water and the bottle was inverted two times. Then two ml of alkali-iodine-azide reagent were added and the bottle again inverted two times. After the manganese sulfate and the alkali-iodine-azide reagent were added, the bottle was allowed to stand until 150 ml of the supernate had cleared. Next two ml of concentrated H<sub>2</sub>SO<sub>4</sub> were added to the BOD bottle by allowing the acid to flow down the neck of the bottle. The bottle was inverted again until dissolution occurred. One hundred ml of the sample was tritrated with .025N sodium thiosulfate until a pale-straw color was observed. One ml of starch solution was added as an indicator and titration continued until the supernate was clear. The number of ml sodium thiosulfate used in the titration x2 equaled mg/l dissolved oxygen.

### Phosphate

Orthophosphate values and total phosphate values were determined with a Coleman Model 6C Junior Spectrophotometer and a Coleman Model 6/35 Junior II Spectrophotometer. The water samples were filtered to remove turbidity before phosphate determinations were made.

### Orthophosphate

Orthophosphate values were determined by the stannous chloride method according to Standard Methods (1971). Two ml of ammonium molybdate and 0.5 ml of stannous chloride were added to 50 ml of distilled water and allowed to develop ten minutes. This sample served as a blank to standardize the instruments before phosphate determinations were made.

Procedure.--Two ml of ammonium molybdate and 0.5 ml of stannous chloride were added to a 50 ml water sample. The sample was allowed to develop ten minutes, but not more than twelve minutes. The absorbance for each sample was recorded at 690 mu and compared to a standard phosphate curve for conversion to mg/l PO<sub>4</sub> (Tables 1-7, pp. 25-31).

### Total Phosphate

Total phosphate values were determined by hydrolyzing the sample with 1N HCL and measuring orthophosphate

by the previously described stannous chloride method. Polyphosphate values were obtained by subtracting orthophosphate values from total phosphate values (Tables 1-7, pp. 25-31).

Procedure.--One ml of 1N HCL was added to the original water sample and autoclaved at 121°C, 15 pounds pressure for twenty minutes. The sample was allowed to reach room temperature and titrated back to pH seven, with 1N NaOH. The remaining procedure for total phosphate determinations was identical with the orthophosphate procedure.

#### Nitrogen

Nitrate-nitrite values were determined by the cadmium reduction method. Nitrite values were determined by the diazotization method and subtracted from nitrate-nitrite values to give nitrates. Ammonium values were determined by the direct Nesslerization method (Hach Chemical Company, 1969). All nitrogen values were obtained using a Bausch and Lomb Spectronic 20.

#### Ammonium Nitrogen

Ammonium nitrogen values were determined by the direct Nesslerization method. The sample temperature is critical during this test and may lead to invalid results if the sample temperature is above or below 20 C. Ammonium

nitrogen values were recorded at 425 mu with a Bausch and Lomb Spectronic 20.

Procedure.--One 25 ml water sample and 25 ml demineralized water sample were measured. One ml of Nessler's reagent was added to each sample. The samples were allowed to develop ten minutes for full color development. A demineralized water sample was then used to standardize the instrument. Percent transmittance values for the prepared water sample were recorded and compared to Hach tables to find the mg/l ammonium nitrogen present in the sample (Hach Chemical Company, 1969).

#### Nitrate

Nitrate values were determined by the cadmium reduction method. Since the cadmium reduction method registered both nitrite and nitrate nitrogen, a nitrite test was run in order to determine nitrate concentrations only. The results of the nitrate test were subtracted from the nitrite test. Nitrite and nitrate values were recorded at 525 mu as percent transmittance.

Procedure.--The contents of one Nitra Ver IV powder pillow were added to a 25 ml water sample and shaken vigorously for one minute. The sample was allowed to develop an additional three minutes for full color development. The original water sample was used as a

blank to standardize the instrument. Nitrate values were recorded as percent transmittance and compared to Hach tables (Hach Chemical Company, 1969) to determine the mg/l nitrate nitrogen present in the water sample (Tables 1-7, pp. 25-31).

#### Nitrite

Nitrite nitrogen values were determined by the diazotization method (Hach Chemical Company, 1969).

Procedure.--To a 25 ml water sample were added the contents of one Nitri Ver powder pillow. The sample was allowed to develop fifteen minutes. The original water sample was used to standardize the instrument. Nitrite values were recorded and compared to Hach tables to find the mg/l nitrite nitrogen present.

#### Plankton

Qualitative and quantitative phytoplankton counts were determined using a Sedgwick-Rafter counting chamber, which is 50 mm long by 20 mm wide by 1 mm deep. A Bausch and Lomb compound microscope and a Wild Heerbrugg compound microscope were used to determine qualitative and quantitative phytoplankton values. A Wild stereoscopic microscope was used to determine total zooplankton numbers.

Quantitative phytoplankton values were determined by the strip count method (Standard Methods, 1971; Ingram

and Palmer, 1952). Filaments, colonies, and aggregations of cells were recorded as one unit. To insure uniformity, the phytoplankton counts were made from fresh samples within four hours after collection. One ml of the plankton sample was placed in the counting chamber, and two drops of methyl cellosolve were added to minimize the movement of flagellates and other motile forms. Two strips the entire length of the counting chamber were counted and all organisms within the fields were enumerated. Several additional strips the length of the counting chamber were counted to determine phytoplankton diversity. All counts were made at 200x using a compound microscope with a whipple eyepiece (reference field) placed in the right ocular. The quantitative counts were then multiplied by a conversion factor to determine the total number of phytoplankton units present in the counting chamber. The conversion factor was determined by dividing the ratio of the width counted to the width of the cell. The original samples were preserved for future reference using formalin, acetic acid, and alcohol (FFA).

Total zooplankton values which include copepods, cladocerans, and rotifers were obtained from the preserved samples using a Wild stereoscopic microscope and petri dish with a reference field placed on the bottom. Total zooplankton values were expressed as organisms per liter (Tables 1-7, pp. 25-31).

Phytoplankton and zooplankton counts were made from concentrated net plankton samples. A total net plankton sample was obtained using a No. 25 Turtox plankton towing net with 200 meshes to the inch. The net was towed 6.10 meters and the amount of concentrated sample was recorded. Since both phytoplankton and zooplankton data are usually expressed as organisms per liter, the total volume of water flowing through the net was calculated. The total volume of water flowing through the net was calculated from the following formula:  $V = \pi R^2 H$ .

The total volume of water flowing through the net was 287 liters.

The total number of phytoplankton units present in the Sedgwick-Rafter cell were converted to organisms per liter using the following formulae:

$$\text{Organisms counted} \left( \frac{\text{No. ml in sample}}{\text{ml counted}} \right) = \frac{\text{organism in concentrated sample}}{\text{sample}}$$

$$\text{No. organisms/liter} = \frac{\text{No. organisms in concentrated sample}}{\text{No. liters flowing through net}}$$

After conversion to organisms per liter the diversity values for each genus were recorded and expressed as organisms per liter. The diversity values (qualitative values) were separated into five separate divisions: the Cyanophycophyta, Chlorophycophyta, Chrysophycophyta, Pyrrophyta, and Euglenophycophyta. Total phytoplankton counts (quantitative counts) for the five divisions were expressed as organisms per liter (Tables 1-7, pp. 25-31). The abundance of Chara

and Nitella, members of the Charophyta, was recorded as percent coverage of the pond bottom.

Photomicrographs of plankton algae occurring at the federal hatchery and the commercial hatchery were taken. The photomicrographs were taken with a Wild Heerbrugg compound microscope and an automatic Nikon camera attachment. A total of seventy-two photomicrographs were taken and each genus described. Notes on field identification and quantitative counts were compiled to aid in the identification of nuisance algae that occurred in the hatchery ponds.

## CHAPTER III

### RESULTS AND DISCUSSION

Data on chemical and physical factors for the selected ponds include pH, temperature, dissolved oxygen, hardness, phosphorus, and nitrogen. Due to the similar chemical and physical characteristics at each hatchery, chemical and physical factors for both were compiled and discussed under the following headings: Temperature, pH, hardness, dissolved oxygen, phosphorus, and nitrogen. The phytoplankton occurring in the individual ponds were discussed by collection sites.

#### Chemical and Physical Factors

Temperature.--The two hatcheries do not differ greatly with respect to pond utilization or, for that matter, individual pond size. The hatcheries differ primarily in age and geographic location. The commercial hatchery is located near Hattiesburg and has been in operation for four years. The federal hatchery is located approximately sixty miles south at Lyman, Mississippi and has been in operation for over thirty years.

A temperature variation of 4° to 5°C was noted between the hatcheries. The temperature differential,

of course, depended upon weather occurring at each location, which resulted in as much as a 7° to 8°C variation on a given sampling day (Tables 1-7, pp. 25-31 ). The temperature differential between the two hatcheries did not reflect any major differences in the diversity of the phytoplankton of the ponds (Tables 8 and 9, pp. 37, 51 ). In fact, the only correlation observed between the algae and temperature was a seasonal succession of each major group. The periodicity of each alga occurring at the hatcheries is discussed at length in the Identification section.

The periodicity of a particular alga was related to temperature and light intensity. The occurrence of all the phytoplankton was recorded on the basis of the time of occurrence during the year, and also if and when maximum concentrations were reached.

pH.--The water sources at both hatcheries contributed to a significant variation of the pH values recorded for the individual ponds of each respective hatchery (Tables 1-7, pp. 25-31 ). At the commercial hatchery the creek water is slightly acidic (6.0-6.5) and contributed to the acidic pH values recorded for the ponds. The Biloxi River and deep wells are the primary water sources at the Lyman Hatchery; both of these are typically acidic. However, liming and pond fertilization over the past thirty

years has resulted in alkaline pond muds. This in turn may have caused the pond waters to be alkaline (Tables 1-7, pp. 25-31).

The pH in the selected ponds at the federal hatchery varied from 6.1 to 10.3 while the pH at the commercial hatchery varied from 5.9 to 8.7. The pH values for the ponds of both hatcheries are listed in Tables 1-7, pp. 25-31).

There were undoubtedly other factors between the hatcheries which were not investigated. These include soil types, leaching of nutrients from surrounding agricultural operations, and obvious differences in fish food application rates between the individual ponds as well as the hatcheries.

Hardness.--All hardness values for the selected ponds were reported as calcium and total hardness; both were expressed as mg/l CaCO<sub>3</sub>.

The average calcium hardness for collection sites at the commercial hatchery was 20.2 mg/l CaCO<sub>3</sub>. By comparison, the average calcium hardness for the federal hatchery was 20.2 mg/l CaCO<sub>3</sub>. Total hardness values on an average for the commercial and federal hatchery were 26 and 35 mg/l CaCO<sub>3</sub> respectively.

Dissolved oxygen.--The lowest dissolved oxygen concentrations (4.0, 4.4 mg/l) at either hatchery occurred in Ponds 1, 3, and 7 at Lyman Hatchery (Tables 1, 3, and 4, August 25, 1971 and November 2, 1971). Fish harvesting operations on November 3, 1971, included the removal of 577,500 fingerlings and followed the 4.4 mg/l dissolved oxygen value recorded for Pond 1, November 2, 1971. Usually dissolved oxygen values at the Lyman Hatchery did not fall below 7.0 mg/l and ranged from a low of 4.0 mg/l to a high of 13.8 mg/l (Tables 1-7, pp. 25-31).

At the commercial hatchery the lowest dissolved oxygen concentration (5.4 mg/l) occurred in the brood and feed-out ponds (Tables 5 and 7). Other ponds at this hatchery usually maintained dissolved oxygen concentrations of 6.0 mg/l or more (Tables 5-7, pp. 29-31 ). However, suboptimal dissolved oxygen concentrations did occur beneath localized blue-green algal mats.

Phosphorus.--Phosphorus concentrations at both hatcheries were usually above minimum requirements (0.015 mg/l) for an algal bloom, but did not directly correlate with quantitative phytoplankton values. In some ponds, however, orthophosphate values were on a few collection dates found to be at minimum requirements (Tables 1, 3, 5, 6, and 7). In most cases the minimum orthophosphate values

corresponded with phytoplankton blooms.<sup>1</sup> However, in Ponds 1 and 5 at the Lyman Hatchery, low phosphorus values (0.01 mg/l) corresponded with low phytoplankton values (Tables 1 and 3, April 20, 1972 and February 20, 1972). A possible explanation for these contradictory correlations between orthophosphate values and phytoplankton values might be that: (1) In the case of the ponds at the commercial hatchery the phytoplankton blooms were utilizing the available phosphate (orthophosphate) and soluble phosphate levels were reduced in the upper water column. (2) At Lyman Ponds 1 and 4 were dense phytoplankton blooms which subsided several days previous to the collection dates. If bacterial decomposition had not released bound phosphorus contained in the algal cells, then it is possible that orthophosphate values were still at limiting concentrations. (3) Further evidence that this was indeed the case in Pond 5 was that the pond received a copper sulfate treatment February 17, 1972. Therefore, the previous assumption that a dense phytoplankton bloom had utilized the available phosphate seemed to be correct.

Phosphorus concentrations (orthophosphate and total phosphate) varied from pond to pond at both hatcheries. Phosphorus concentrations also varied from one collection

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<sup>1</sup>Phytoplankton bloom--500 organisms per ml of water or as defined by Palmer (1959): "A concentrated growth or aggregation of plankton, sufficiently dense as to be readily visible."

date to the next (Tables 1-7, pp. 25-31 ). At the commercial hatchery the average orthophosphate for the selected ponds was 0.171 mg/l phosphorus. The highest recorded orthophosphate value (0.975 mg/l) occurred in the feed-out pond at Ole Joe's Hatchery on November 8, 1971 (Table 5, pp. 29 ). The average orthophosphate for the four ponds at the Lyman Hatchery was 0.217 mg/l phosphorus with the highest recorded orthophosphate (0.900 mg/l) occurring in Pond 3 on March 17, 1972 (Table 2, pp. 26 ).

As with orthophosphate values, correlations between total phosphorus concentrations and phytoplankton were not clear. On some collection dates total phosphorus values indicated that dense blooms were releasing bound polyphosphates. However, this correlation did not always hold true.

As such the variations of phosphorus concentrations between the individual ponds of both hatcheries on the same as well as different collection dates were probably best reflected by the individual fish food application rates of the ponds. Inorganic fertilization with fertilizers and organic fertilization by fish foods may have increased the phosphorus levels within the ponds. In addition, fish excretion in heavily stocked ponds probably increased phosphorus concentrations. At the Lyman Hatchery the well water is high in soluble phosphate, which may have increased phosphorus levels within the ponds.

Nitrogen.--Careful analysis of the nitrogen data from ponds at both hatcheries has left the writer uncertain as to whether or not nitrogen was a limiting factor for phytoplankton growth (particularly blue-green algae) in the hatchery ponds. At any rate nitrogen values (ammonium and nitrate nitrogen) correlated more closely with phytoplankton values than did phosphorus values. On most collection dates ammonium concentrations and in some instances nitrate concentrations followed increases in total phytoplankton. As the phytoplankton increased ammonium concentrations declined; and on many occasions a corresponding decrease of nitrate nitrogen along with decreasing ammonium nitrogen values were noted (Tables 2, 4, 7, pp. 26, 28 and 31 ). Frequently when the blooms subsided, ammonium and nitrate nitrogen values increased, although this was not always the case.

Nitrogen data for the ponds at both hatcheries indicated that the algae were utilizing ammonium and nitrate nitrogen about equally, depending on the concentration of nitrate nitrogen, i.e., if the nitrate nitrogen was below minimum requirements. This phenomena may not have actually been the case since low nitrate values are not necessarily indicative of limiting nitrogen concentrations. Ammonium concentrations were usually above minimum requirements (0.30 mg/l) as described by Sawyer (1947). Therefore, the algae could have been utilizing the ammonium nitrogen.

The highest recorded ammonium nitrogen value (2.35 mg/l) for the ponds of both hatcheries occurred in a channel catfish feed-out pond at the commercial hatchery (Table 5, March 7, 1972). Ammonium concentrations were highest in ponds heavily stocked with fish. This seems to be in agreement with Murphy and Pippet (1970) who stated that excretions by channel catfish increase nitrogen concentrations.

Nitrate nitrogen concentrations for the selected ponds of both hatcheries usually remained below 0.100 mg/l but did approach minimum requirements on several collection dates (Tables 4-6, Pond 7, January 27, 1972).

From the correlations observed between nitrogen concentrations and phytoplankton for the selected ponds, it is the opinion of the writer that the variation of nitrogen values between the individual ponds on the same and different collection dates, as well as any lack of correlation on specific sampling dates, were probably the result of: (1) the increased nitrogen levels of ponds heavily stocked with fish. (2) a variation of water inflow and outflow through seepage and draining of the ponds. (3) the addition of nitrogen by rainfall or the resulting leaching of nutrients caused by rainfall. (4) the individual fish food application rates of the ponds, and the removal of fish from the pond by fish harvesting operations. The detrimental effect of copper sulfate treatments on the phytoplankton often prevented correlations between algal numbers and nutrient values.

TABLE 1  
 COMPARISON OF CHEMICAL CHARACTERISTICS, TOTAL NET PHYTOPLANKTON,  
 AND ZOOPLANKTON DURING YEARLY COLLECTIONS IN  
 POND 1 LYMAN HATCHERY

	Hardness mg/l		D.O.	Temp. °C	pH	Phosphorus (P) mg/l		Nitrogen (N) mg/l		ZOO- Plankton Org/l	Phyto- Plankton Org/l
	Ca	Total				Ortho	Total	NH <sub>4</sub>	NO <sub>3</sub>		
04/27/71	30	45	7.1	.	.	.	.	.	.	0.0	0.0
05/24/71	15	30	9.6	27	9.5	.	.	.	.	9.7	1,399.2
06/10/71	.	.	7.8	28	7.1	0.250	0.375	0.40	0.089	18.0	1,916.0
07/02/71	15	30	7.2	28	9.3	0.100	0.125	0.77	0.047	5,146.0	12,638.0
07/24/71	15	15	8.6	31	8.0	0.450	0.974	0.61	0.131	4.6	210.7
08/25/71	15	60	8.2	31	8.4	0.510	0.624	0.64	0.057	540.0	21,388.0
09/20/71	15	45	12.0	30	6.8	0.150	0.230	0.48	0.044	75.1	5,526.2
11/02/71	15	45	4.4	28	7.5	0.234	0.410	0.66	0.075	240.6	5,624.3
11/22/71	15	30	7.2	20	8.5	0.954	0.974	0.21	0.077	0.0	5,320.0
04/20/72	15	30	8.4	27	7.7	0.010	0.130	0.86	0.032	0.0	169.4

TABLE 2

COMPARISON OF CHEMICAL CHARACTERISTICS, TOTAL NET PHYTOPLANKTON,  
AND ZOOPLANKTON DURING YEARLY COLLECTIONS IN  
POND 3 LYMAN HATCHERY

	Hardness mg/l		D.O.	Temp. °C	pH	Phosphorus (P) mg/l		Nitrogen (N) mg/l		Zoo- Plankton Org/l	Phyto- Plankton Org/l
	Ca	Total				Ortho	Total	NH <sub>4</sub>	NO <sub>3</sub>		
05/24/71	30	30	9.2	27	9.9	0.050	0.540	.	0.079	1.9	570.0
06/10/71	15	15	7.0	28	8.0	0.050	0.100	1.31	0.070	23.8	111.8
07/02/71	15	45	6.8	30	8.0	0.050	0.065	0.66	0.047	236.0	15,735.0
07/24/71	15	15	8.4	31	8.2	0.150	0.210	0.58	0.055	35.1	1,175.8
08/25/71	30	30	6.4	31	8.1	0.204	0.330	0.50	0.099	3.0	67,738.0
09/20/71	45	75	12.0	31	8.4	0.170	0.180	0.50	0.064	95.2	189.9
11/02/71	60	75	4.0	26	7.0	0.420	0.490	0.75	0.100	30.8	1,507.2
11/22/71	45	60	7.8	18	8.2	0.065	0.250	0.45	0.060	25.1	8,206.8
01/06/72	45	75	8.0	21	6.3	0.230	0.434	0.30	0.044	54.8	1,714.0
01/27/72	45	60	8.6	20	8.7	0.174	0.210	0.48	0.069	33.3	1,742.5
02/20/72	30	45	9.6	20	10.3	0.250	0.324	0.95	0.037	28.2	431.8
03/16/72	15	30	8.4	23	7.0	0.900	0.976	1.17	0.054	191.1	3,036.0
04/20/72	30	30	13.8	26	8.3	0.130	0.150	0.92	0.037	56.8	1,044.4

TABLE 3

COMPARISON OF CHEMICAL CHARACTERISTICS, TOTAL NET PHYTOPLANKTON,  
AND ZOOPLANKTON DURING YEARLY COLLECTIONS  
POND 5 LYMAN HATCHERY

	Hardness mg/l	Ca Total	D.O.	Temp. °C	pH	Phosphorus (P) mg/l		Nitrogen (N) mg/l		Zoo- Plankton Org/l	Phyto- Plankton Org/l
						Ortho	Total	NH <sub>4</sub>	NO <sub>3</sub>		
06/10/71	15	15	9.0	27	7.6	0.190	0.350	1.07	0.10	0.0	860.0
07/02/71	15	15	8.0	31	6.5	0.750	0.500	0.69	0.055	144.0	30,579.0
07/22/71	15	15	5.6	31	8.0	0.150	0.410	0.89	0.138	0.0	1,140.2
08/25/71	30	75	6.4	31	7.2	0.070	0.110	0.61	0.085	28.9	4,331.2
09/20/71	15	15	10.0	30	6.1	0.090	0.130	0.48	0.037	83.3	4,100.3
11/02/71	15	15	5.0	26	7.6	0.050	0.110	0.50	0.089	20.7	9,610.2
11/22/71	15	30	7.8	17	8.0	0.070	0.110	0.37	0.094	1.0	171.4
12/14/71	15	15	8.0	23	8.2	0.210	0.270	0.37	0.135	50.7	1,332.8
01/06/71	15	30	8.8	21	6.1	0.050	0.130	0.15	0.084	46.8	5,836.6
01/27/72	15	30	6.0	19	7.4	0.154	0.190	0.50	0.069	19.4	1,630.8
02/20/72	15	30	6.8	19	8.6	0.010	0.124	1.75	0.044	7.1	798.3
03/16/72	15	30	13.4	22	6.4	0.150	0.250	0.64	0.055	18.6	1,169.1
04/20/72	15	30	9.4	27	7.6	0.420	0.482	0.83	0.057	19.4	7,633.0

TABLE 4

COMPARISON OF CHEMICAL CHARACTERISTICS, TOTAL NET PHYTOPLANKTON,  
AND ZOOPLANKTON DURING YEARLY COLLECTIONS IN  
POND 7 LYMAN HATCHERY

	Hardness mg/l		D.O.	Temp. °C	pH	Phosphorus (P) mg/l		Nitrogen (N) mg/l		Zoo- Plankton Org/l	Phyto- Plankton Org/l
	Ca	Total				Ortho	Total	NH <sub>4</sub>	NO <sub>3</sub>		
04/27/71	15	45	7.0	28	7.5	0.125	0.050	0.89	0.107	75.7	141.3
06/10/71	15	15	7.6	30	8.2	0.090	.	0.77	0.060	7.4	460.8
07/02/71	15	15	6.0	31	8.0	0.105	0.200	0.89	0.138	5,752.0	733,496.0
07/24/71	15	15	5.6	31	8.1	0.130	0.020	0.56	0.090	121.9	1,334.7
08/25/71	15	45	4.0	30	6.1	0.030	0.100	0.45	0.055	2.0	17,085.0
09/20/71	15	30	10.0	26	7.4	0.110	0.100	0.61	0.077	58.4	2,777.4
11/02/71	15	45	6.4	18	8.2	0.150	0.020	0.40	0.070	58.2	1,265.4
11/22/71	15	30	8.8	22	6.5	0.025	0.065	0.58	0.127	19.6	596.7
12/14/71	15	30	8.2	21	6.2	0.090	0.120	0.00	0.094	35.1	349.2
01/06/72	15	30	8.8	20	8.0	0.154	0.076	0.66	0.270	148.4	5,347.9
01/27/72	15	30	9.4	19	8.7	0.550	0.000	1.70	0.025	18.0	1,035.0
02/20/72	15	30	7.0	22	7.3	0.050	0.080	0.86	0.062	40.1	2,030.4
03/15/72	15	30	9.0	27	7.6	0.090	0.040	0.86	0.055	86.1	2,900.7
04/20/72	15	30	9.0	27	7.6	0.090	0.040	0.86	0.055	32.3	2,317.5

TABLE 5

COMPARISON OF CHEMICAL CHARACTERISTICS, TOTAL NET PHYTOPLANKTON,  
AND ZOOPLANKTON DURING YEARLY COLLECTIONS IN  
FEED OUT POND, OLE JOE'S HATCHERY

	Hardness mg/l		D.O.	Temp. °C	pH	Phosphorus (P) mg/l		Nitrogen (N) mg/l		Zoo- Plankton Org/l	Phyto- Plankton Org/l
	Ca	Total				Ortho	Total	NH <sub>4</sub>	NO <sub>3</sub>		
05/05/71	15	30	10.0	26	6.6	0.010	0.150	. .	0.071	0.0	8,008.2
05/31/71	15	15	10.0	25	6.5	0.025	0.250	1.15	0.087	252.2	4,819.4
06/16/71	15	15	10.2	30	6.4	0.110	0.265	0.18	0.015	62.3	3,091.5
07/02/71	15	15	9.8	35	8.7	0.075	0.130	0.53	0.095	98.2	8,205.0
07/22/71	. .	. .	9.4	36	6.4	. .	. .	. .	. .	51.3	5,791.3
08/06/71	. .	. .	9.0	36	6.4	. .	. .	. .	. .	16.8	2,223.0
09/07/71	15	30	5.4	30	6.5	0.230	0.290	0.37	0.099	1.9	8,099.3
10/18/71	15	45	14.0	29	6.6	0.270	0.430	1.17	0.299	15.7	23,578.6
11/08/71	15	30	10.4	20	7.5	0.975	1.035	0.21	0.080	63.1	4,922.2
12/01/71	15	45	8.2	13	6.0	0.375	0.525	1.46	0.085	155.0	3,757.5
12/27/71	15	30	8.0	21	8.2	0.290	0.310	0.43	0.011	35.9	4,686.3
01/18/72	15	30	9.0	10	7.2	0.150	0.184	0.64	0.057	15.8	26,528.9
02/14/72	15	30	7.0	12	7.9	0.070	0.110	0.64	0.020	73.7	43,364.6
03/07/72	15	30	12.0	18	8.1	0.010	0.110	2.35	0.10	145.3	31,692.3

TABLE 6

COMPARISON OF CHEMICAL CHARACTERISTICS, TOTAL NET PHYTOPLANKTON,  
AND ZOOPLANKTON DURING YEARLY COLLECTIONS IN  
FINGERLING POND, OLE JOE'S HATCHERY

	Hardness mg/l		D.O.	Temp °C	pH	Phosphorus (P) mg/l		Nitrogen (N) mg/l		ZOO- Plankton Org/l	Phyto- Plankton Org/l
	Ca	Total				Ortho	Total	NH <sub>4</sub>	NO <sub>3</sub>		
05/31/71	15	15	8.0	26	5.9	0.070	0.100	0.800	0.159	71.7	3,944.7
06/16/71	15	15	8.0	30	7.2	0.010	0.050	0.860	0.139	20.4	4,755.6
07/02/71	15	30	10.0	36	7.3	0.010	0.130	0.530	0.100	49.4	6,100.0
07/22/71	.	.	9.4	36	6.4	.	.	.	.	50.8	4,182.3
08/06/71	.	.	9.4	36	6.4	.	.	.	.	357.3	904.5
09/07/71	15	30	9.2	30	6.4	0.184	0.210	2.13	0.027	82.5	7,520.4
10/18/71	15	60	10.0	29	6.0	0.110	0.250	0.980	0.072	35.8	4,690.0
11/08/71	15	15	9.0	20	7.8	0.475	0.525	0.250	0.080	102.7	4,196.8
12/01/71	15	30	7.8	15	6.1	0.525	0.675	0.500	0.145	37.9	4,443.8
12/27/71	15	30	6.6	21	8.3	0.430	0.950	0.400	0.099	64.9	1,912.5
01/18/71	15	30	8.2	15	7.1	0.070	0.130	0.48	0.094	35.6	3,384.0
02/14/72	15	30	7.4	12	8.6	0.010	.	0.400	0.040	195.8	855.0
03/07/72	15	15	6.0	18	6.4	0.050	0.130	0.580	0.042	14.9	2,747.7
03/30/72	15	30	11.4	19	7.5	0.050	0.090	0.800	0.034	25.8	22,945.0
04/20/72	15	30	.	24	7.9	0.070	0.090	0.640	0.052	62.9	4,000.0

TABLE 7

COMPARISON OF CHEMICAL CHARACTERISTICS, TOTAL NET PHYTOPLANKTON,  
AND ZOOPLANKTON DURING YEARLY COLLECTIONS IN  
BROOD POND, OLE JOE'S HATCHERY

	Hardness		D.O.	Temp. °C	pH	Phosphorus (P) mg/l		Nitrogen (N) mg/l		Zoo- Plankton Org/l	Phyto- Plankton Org/l
	Total	Ca				Ortho	Total	NH <sub>4</sub>	NO <sub>3</sub>		
05/05/71	15	15	10.0	26	6.5	0.005	0.060	.	0.069	0.0	6,164.1
05/19/71	15	15	9.0	24	6.5	0.015	0.095	1.1	0.080	21.5	10,638.2
05/31/71	15	15	6.0	24	6.6	0.115	0.315	1.62	0.122	39.9	5,415.4
06/16/71	15	15	7.0	30	8.0	0.130	1.00	0.580	0.077	163.0	109,310.4
07/02/71	15	30	5.4	37	6.6	0.250	0.075	0.058	0.109	0.0	1,515.6
07/22/71	.	.	.	.	.	.	.	.	.	69.2	40,637.6
08/06/71	.	.	9.0	33	6.4	.	.	.	.	25.7	903.6
12/01/71	15	30	7.8	15	6.1	0.525	0.675	0.610	0.199	15.7	5,010.4
12/27/71	15	15	5.8	21	8.4	0.374	0.470	0.720	0.117	66.0	3,699.0
01/18/72	15	30	9.4	15	6.8	0.030	0.090	0.720	0.079	4.0	9,100.0
02/14/72	15	30	6.0	12	7.5	0.010	0.070	0.300	0.270	16.9	6,467.8
03/07/72	15	15	7.6	17	7.2	0.025	0.050	0.830	0.037	283.6	3,682.8
03/30/72	15	15	11.6	19	7.3	0.010	0.410	1.08	0.057	38.9	49,096.8
04/20/72	15	15	4.0	24	7.4	0.250	0.250	1.46	0.080	22.8	2,066.4

### Summary of Chemical and Physical Data

The correlations observed between phytoplankton occurrence and chemical and physical data were supported in part by literature in the field of phytoplankton ecology.

A temperature differential of 4° to 5°C between the hatcheries did not reflect any major differences in phytoplankton diversity. In conjunction with Whitford and Schumacher (1967), algal periodicity was directly related to temperature and light intensity. The major bloom causers were more susceptible to changes in temperature and light intensity. More detailed information concerning the temperature requirements of the major bloom-causers should prove meaningful.

Calcium and total hardness values, which were used by Welch (1952) as indicators of productivity in natural waters were not indicative of either phytoplankton or fish production. In agreement with Boyd (1966) total hardness values were higher in ponds where certain plants selective of hard waters were found. For example, Hydrodictyon occurred in ponds where total hardness values were consistently higher than those of adjacent ponds.

Acceptable dissolved oxygen levels were dependent on phytoplankton production and were critical since they insured that maximum fish production for each pond was achieved. Copper sulfate treatments tended to lower dissolved oxygen levels, which was consistent with the findings of Swingle (1968).

Correlations between phosphorus values and phytoplankton were obscured by several factors. Phosphorus values indicated areas of high algal productivity, but were often far removed from the factors which account for the periodicity and diversity of algae in hatchery ponds. This is in agreement with Lund (1965), who is of the opinion that nitrogen and phosphorus are probably the two critical elements limiting phytoplankton production, but other factors which include grazing of phytoplankton by invertebrates and inhibitory substances produced by algae and aquatic macrophytes, play an important role in the distribution and diversity of algae. Hrbacek (1964) also concluded that blue-green algal blooms were not totally dependent on nitrogen or phosphorus concentrations. More specifically, the algal blooms at the hatcheries occasionally occurred when nitrogen or phosphorus were limiting. The ability of blue-green algal blooms to flourish when nutrients were limiting was accounted for in part by their ability to fix elemental nitrogen, confirming the reports of Stewart (1967), Allen (1965), Williams and Burris (1952). Further, orthophosphate usually constituted less than 10 percent of the total phosphorus in the pond water making correlations between phytoplankton and orthophosphate difficult. This agrees with Shapiro (1959). On the other hand, as reported by Abbott (1957) phytoplankton may utilize complex organic phosphate when orthophosphate is not present. This further

complicated the problem of obtaining correlations between phytoplankton and phosphorus concentrations.

In this investigation, correlations were sought between phytoplankton and nitrogen in an attempt to account for the periodicity, diversity, and abundance of algae in hatchery ponds. It is well known that both phosphorus and nitrogen are considered the two essential nutrients needed for growth by the algae, but the importance of these nutrients in accounting for the diversity of algae in hatchery ponds is questionable. Hutchinson (1944) reported that correlations were possible between nitrogen and phosphorus, but did not necessarily account for the diversity of algae or the emergence or decline of any one particular alga.

Inorganic nitrogen was one of the major nutrients added to the hatchery pond to increase fish production. However, Swingle (1963) reported that the elimination of inorganic nitrogen for the ponds would not decrease fish production if nitrogen were added for several years. However, Green (1968) said that the addition of organic nitrogen in the form of cotton seed meal or fish excrement increases production substantially. Therefore, a ready source of nitrogen was available either through fertilization or biologically fixed nitrogen. The fact that non-nitrogen fixing blue-green are dependent on nitrogen concentrations while nitrogen fixing blue-green algae are dependent on phosphorus concentrations was probably a

factor limiting the growth of bloom-causing blue-green algae in the hatchery ponds. This observation is in agreement with Fitzgerald (1969) and Gerloff (1952).

### Plankton by Collection Sites

#### Lyman National Fish Hatchery

Four ponds differing in size, utilization, and treatment were chosen for investigation at the Lyman National Fish Hatchery. Variations in total phytoplankton production, diversity, and periodicity were noted among the ponds. Each pond received inorganic fertilization and copper sulfate treatments for the control of nuisance algae.

Pond 1. --Pond 1 is a bass-bluegill rearing pond covering approximately ten surface acres, and is the largest pond at the Lyman Hatchery. This pond was characterized by a profuse mat of Hydrodictyon (Illus. 25) that covered approximately 25 to 40 percent of the surface from April to November. Several ponds, other than the regular collection sites, had dense floating mats of either Pithophora or Hydrodictyon (Illus. 25, 33) while the other regular collection sites (Ponds 3, 5, and 7) did not have visible mats throughout this investigation.

The pond was partially filled on April 27, 1971, (the initial collection for Pond 1) and completely filled

and stocked on July 22 with 2,000 adult bluegill and 100 intermediate largemouth bass. Total fish production in 1971 was 1,027,500 bass and bluegill fingerlings, all harvested during November. The pond was drained on December 8, and later refilled during April of 1972. The final collection for Pond 1 was on April 20, 1972.

Commerical fish food was added to the pond in the following amounts: September, ten pounds Splash No. 1; October, ninety pounds Splash No. 1; November, fifteen pounds Cloverbrand. These rates were less than the application rates of the channel catfish rearing ponds (5 and 7).

Pond 1 received two copper sulfate applications initiated to control the large mat of Hydrodictyon covering the pond surface. However, the copper sulfate treatments on August 13 and August 19, 1971 failed to control the mat which remained at previous levels until late November. The effects of water level fluctuation and the copper sulfate treatments on Hydrodictyon are discussed in the identification section.

Plankton analysis for Pond 1 consisted only of net plankton and indicated that a total of forty algal genera comprising four divisions were present (Table 8). The relative abundance of these algae is summarized in Tables 1 and 8. Their periodicity is depicted in Figure 3. Only two genera approached bloom conditions on two

TABLE 8  
 CUMULATIVE LIST OF ALGAL GENERA AND TOTAL UNITS  
 OF EACH GENUS FOUND AT THE LYMAN HATCHERY  
 DURING THE SAMPLE PERIOD

	No. 1	No. 3	No. 5	No. 7
<u>Cyanophycophyta</u>				
<u>Anabaena</u>	23,216	600	3,184	4,219
<u>Aphanizomenon</u>	12	. . .	9,082	. . .
<u>Calothrix</u>	. . .	35	. . .	. . .
<u>Coelosphaerium</u>	. . .	17	. . .	74,844
<u>Cylindrospermum</u>	5	. . .	. . .	. . .
<u>Dactyococcopsis</u>	. . .	. . .	. . .	17
<u>Gleocapsa</u>	. . .	70	. . .	. . .
<u>Gleotheca</u>	. . .	45	. . .	. . .
<u>Comphosphaeria</u>	. . .	17	. . .	. . .
<u>Lyngbya</u>	. . .	. . .	. . .	35
<u>Merismopedia</u>	. . .	. . .	32	202
<u>Oscillatoria</u>	1,671	257	137	757
<u>Phormidium</u>	67	. . .	. . .	. . .
<u>Polycystis</u>	. . .	10	119	484
<u>Rivularia</u>	4	. . .	. . .	. . .
Total	24,908	1,051	12,554	80,558
<u>Chlorophycophyta</u>				
<u>Ankistrodesmus</u>	10,760	31	. . .	. . .
<u>Arthrodesmus</u>	211	. . .	. . .	. . .
<u>Chlamydomonas</u>	608	. . .	. . .	. . .
<u>Chlorella</u>	. . .	87	. . .	211
<u>Closteriopsis</u>	35	. . .	. . .	. . .
<u>Closterium</u>	44	. . .	2,349	70
<u>Coelastrum</u>	. . .	4,860	. . .	8,031
<u>Cosmarium</u>	157	5	145	21,405
<u>Desmidium</u>	5	167	67	. . .
<u>Dictyosphaerium</u>	211	7,597	7,432	32,250
<u>Dimorphococcus</u>	. . .	6	7	35
<u>Eremosphaera</u>	64	70	67	871
<u>Eudorina</u>	764	217	3,577	74,966
<u>Filamentous</u>	85	103	542	10,709
<u>Hormidium</u>	. . .	. . .	. . .	370

TABLE 8 (Cont.)

	No. 1	No. 3	No. 5	No. 7
<u>Kirchneriella</u>	. . .	324	7	. . .
<u>Micrasterias</u>	41	. . .	105	35
<u>Mougeotia</u>	. . .	. . .	. . .	35
<u>Netrium</u>	31	. . .	382	45
<u>Pachycladon</u>	. . .	. . .	32	. . .
<u>Pandorina</u>	1,723	. . .	. . .	28
<u>Pediastrum</u>	363	527	182	5,469
<u>Pithophora</u>	. . .	. . .	. . .	13
<u>Playdorina</u>	. . .	. . .	. . .	44
<u>Pleodorina</u>	. . .	. . .	136	44
<u>Pleurotaenium</u>	. . .	. . .	. . .	10
<u>Scenedesmus</u>	2,053	5,711	500	4,603
<u>Selenastrum</u>	. . .	35	1,489	102
<u>Spirogyra</u>	190	. . .	193	211
<u>Staurastrum</u>	2,062	1,483	3,186	33,917
<u>Ulothrix</u>	103	4,837	12,362	2,196
<u>Unicells</u>	1,973	1,823	12,053	163,157
<u>Volvocalean</u>	. . .	. . .	. . .	. . .
<u>Volvox</u>	19	. . .	35	2
<u>Xanthidium</u>	2	162	7	. . .
<u>Zygnema</u>	497	99	8	. . .
<b>Total</b>	<b>22,001</b>	<b>28,144</b>	<b>44,961</b>	<b>358,817</b>
<b>Chrysophycophyta</b>				
<u>Asterionella</u>	. . .	18	7	289
<u>Bidulphia</u>	. . .	. . .	184	4
<u>Cyclotella</u>	. . .	52,488	92	. . .
<u>Diatoma</u>	372	216	. . .	. . .
<u>Diatoms</u>	320	5,116	7	197
<u>Dinobryon</u>	. . .	8	1,624	78
<u>Fragilaria</u>	8,717	7,327	4,262	356
<u>Mallomonas</u>	. . .	. . .	. . .	264
<u>Meridion</u>	. . .	. . .	. . .	4
<u>Melosira</u>	. . .	35	. . .	. . .
<u>Navicula</u>	369	1,922	504	320,797
<u>Nitzschia</u>	3	. . .	. . .	. . .
<u>Pinnularia</u>	354	496	13	. . .
<u>Rhizosolenia</u>	5	167	. . .	. . .
<u>Surirella</u>	. . .	17	. . .	6
<u>Synedra</u>	242	874	732	472
<u>Synura</u>	. . .	. . .	. . .	105
<u>Tabellaria</u>	. . .	. . .	. . .	2
<u>Tribonema</u>	742	7,255	3,072	2,416
<b>Total</b>	<b>11,121</b>	<b>75,939</b>	<b>10,497</b>	<b>324,990</b>

TABLE 8 (Cont.)

	No. 1	No. 3	No. 5	No. 7
<b>Pyrrhophycophyta</b>				
<u>Ceratium</u>	47	679	136	149
<u>Peridinium</u>	117	35	40	15
Total	164	714	176	164
<b>Euglenophycophyta</b>				
<u>Euglena</u>	. . .	. . .	187	121
<u>Phacus</u>	. . .	324	7	. . .
Total	. . .	324	194	121

Pond 1--Algal units compiled from ten collection dates.

Pond 3--Algal units compiled from thirteen collection dates.

Pond 5--Algal units compiled from thirteen collection dates.

Pond 7--Algal units compiled from fourteen collection dates.

separate occasions. On July 2, 1971 Ankistrodesmus (Illust. 12) constituted 85 percent of the total algae, and on August 25, 1971 Anabaena (Illust. 1, 2) constituted 98 percent of the total (Table 1). Total zooplankton values also reached maximum concentrations (5,146 organisms per liter) on July 2 and were higher than on any other collection date (Table 1).

Members of the Chlorophycophyta were the most conspicuous (phytoplankton) with Staurastrum (Illust. 39) usually the most prevalent form. These algae were the dominant organisms throughout the early spring and summer, and were followed by the blue-green algae during the late summer (July and August). Diatoms and other Chrysophycophyta were the most conspicuous algae during September and late November. After the final November collection the pond was drained and remained so until April, 1972.

Pond 3.--This pond is a bass-brood pond approximately three acres in surface area. Regular collections began on April 27, 1971 and continued until April 20, 1972. Records of fish production and fish food application rates were not available for this pond.

Total net plankton for the pond is summarized in Tables 3 and 8. Most of the phytoplankton present consisted of green and yellow-green algae with the blue-green algae always constituting less than 17 percent of the

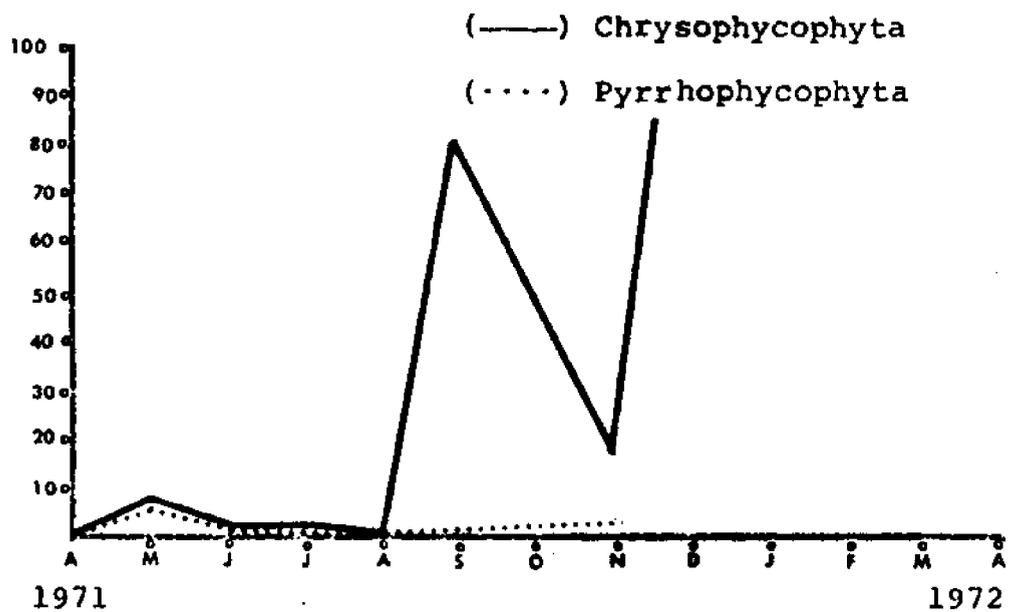
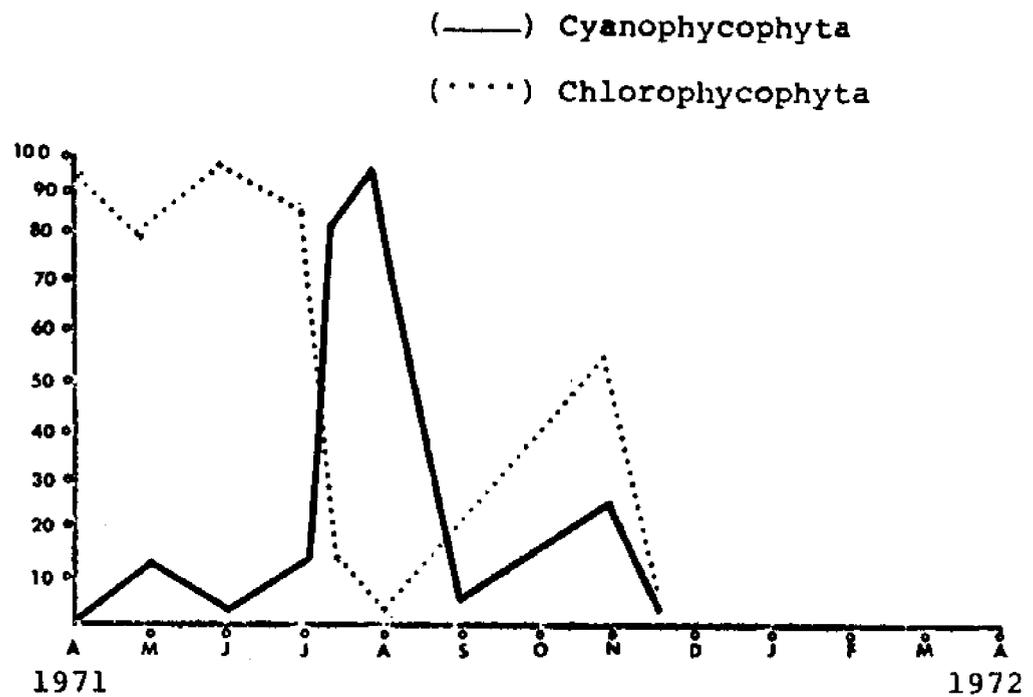


Fig. 3.--Monthly Percentage Composition of Phytoplankton at the Divisional Level in Pond 1 at the Lyman Hatchery.

total plankton. The blue-greens were more conspicuous during the spring as compared to other ponds where higher values were recorded during the fall. Throughout the spring and summer the green algae were the dominant algae, and were followed by the yellow-green algae as the dominant forms from August until late January. During late January the green algae were again the predominant algae, but declined during February as yellow-green algae, (primarily Tribonema, Illust. 65, 66) exceeded the previous percentages of early January. The Pyrrhophycophyta also reached maximum concentrations at that time (Fig. 4).

Phytoplankton values in March, 1972 exceeded those of February and indicated that diatoms were the dominant forms (Table 3) whereas, a bright green water color and a characteristic musty odor indicated that a green algal bloom was present. In fact, the analysis of an additional water sample revealed that these phenomena were produced by a dense bloom of Chlorella (Illust. 15). In adjacent ponds at the Lyman Hatchery green algal blooms occurred primarily during the summer, and were not as intense as the bloom of Chlorella.

As in most other ponds at the Lyman Hatchery, Ulothrix was the most abundant filamentous algae, and Staurastrum, Scenedesmus, and Pediastrum were common non-filamentous taxa (Illust. 31, 37, 39, & 43). Dictyosphaerium and Dimorphococcus were often the predominant

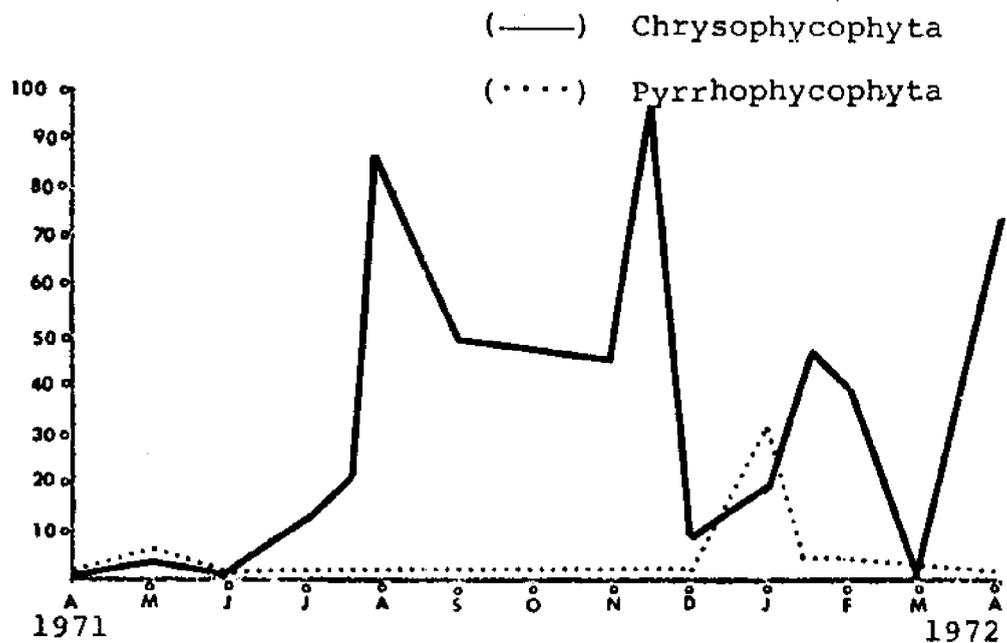
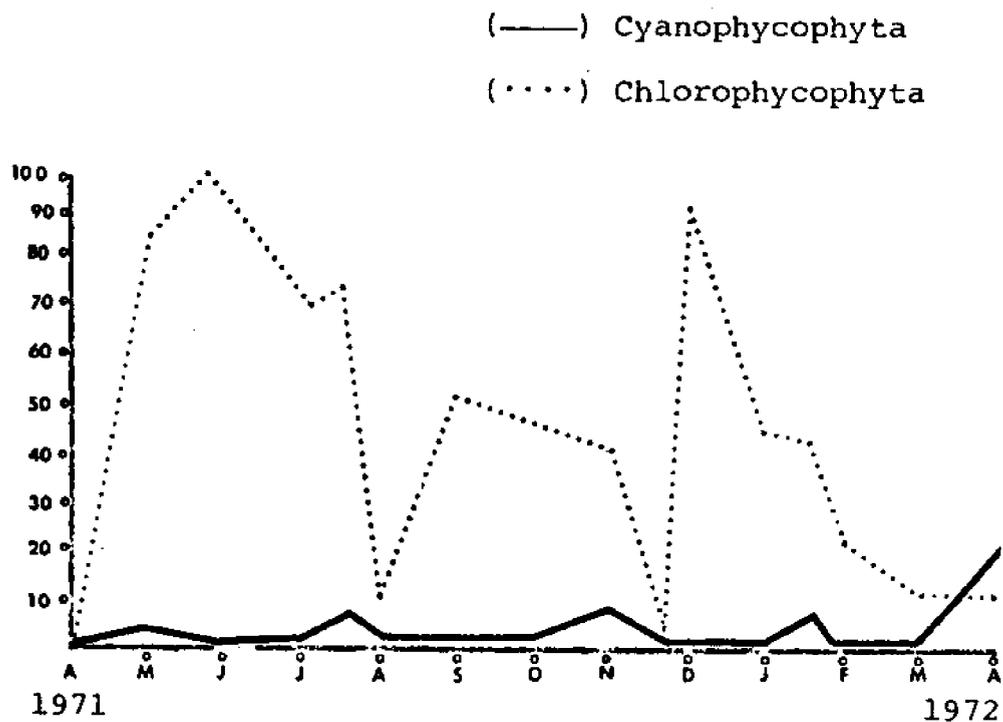


Fig. 4.--Monthly Percentage Composition of Phytoplankton at the Divisional Level in Pond 3 at the Lyman Hatchery.

green algae during the summer. Fragilaria followed by Pinnularia and Synedra (Illust. 57) were the most prevalent yellow-greens. The dinoflagellates and Euglenoids, although present on occasion, were consistently minor components of the plankton (Illust. 67, 68, 69, 70).

Pond 5.--This pond is one of the two channel catfish rearing ponds that cover 0.5 acres in surface area. The pond was first chosen for investigation on April 27, 1971, but was drained at that time. Regular collections began on June 10, 1971 and continued until April 20, 1972.

The pond was initially stocked on May 21, 1971 with forty-five adult male and female channel catfish. Later supplemental stocking during June, July, and November included a combined total of 108 intermediate channel catfish. Records of pond production included only fish food application rates which averaged 194 pounds per month from May to November.

Pond 5 received two copper sulfate applications (0.5 pound), one June 15, 1971 and the second application on February 17, 1972. Total phytoplankton values were higher on the July 2 collection as compared with the previous collection in June (Table 3). Eudorina, Dictyosphaerium, and Anabaena (Illust, 1, 22) were all present during June and increased substantially after the copper sulfate treatment (Table 3, July 2, 1971). The only decrease in total phytoplankton noted for any pond

occurred after the copper sulfate treatment during February, 1972 (Table 3, February 20, 1972).

In Pond 5 the periodicity of the five recorded divisions was similar to that of an adjacent channel catfish rearing pond (Figures 4 and 5). Both had similar physical and chemical characteristics and received approximately the same amount of inorganic and organic fertilization. In these ponds the diatoms and blue-green algae were present at approximately the same season of the year as adjacent ponds. However, the diatoms in particular were usually found in higher concentrations than in other ponds. These algae frequently reached bloom proportions during the fall and unlike other ponds where green algae followed their decline, blue-green algae became more abundant.

Pond 7.--This pond is a channel catfish rearing pond located directly adjacent to Pond 5. Regular collections were made from April 27, 1971 to April 20, 1972. Pond 7 was stocked in June, 1971 with thirty-four adult channel catfish, and additionally stocked during July and November with a combined total of fifty-seven intermediate channel catfish. Fish food application rates averaged 205 pounds per month from July to November.

Pond 7 received one copper sulfate application on March 10, 1972. Once again total phytoplankton increased over the previous collection (Table 4). The most significant increase occurred among the green algae, e.g.,

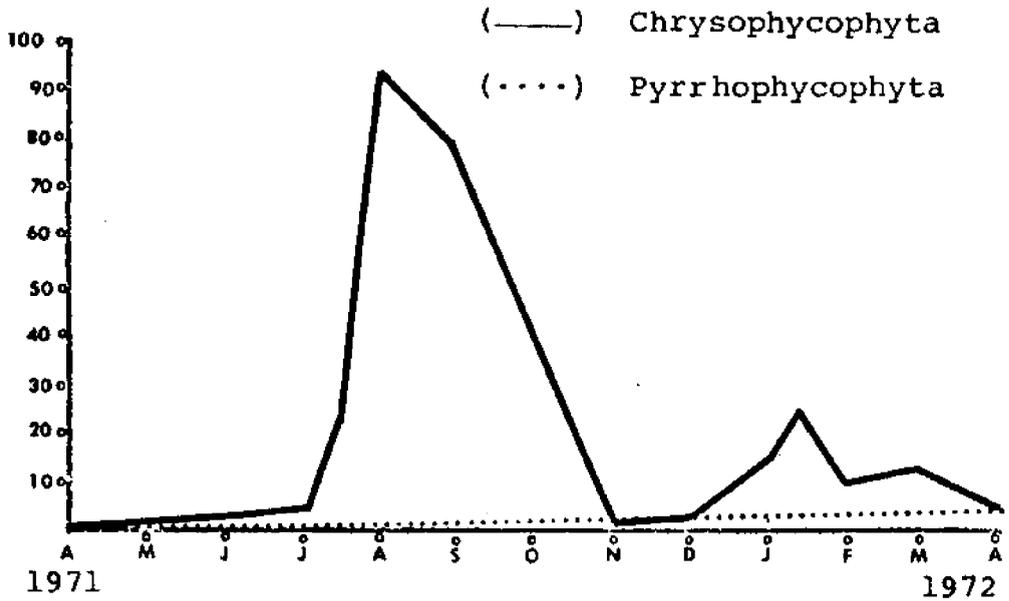
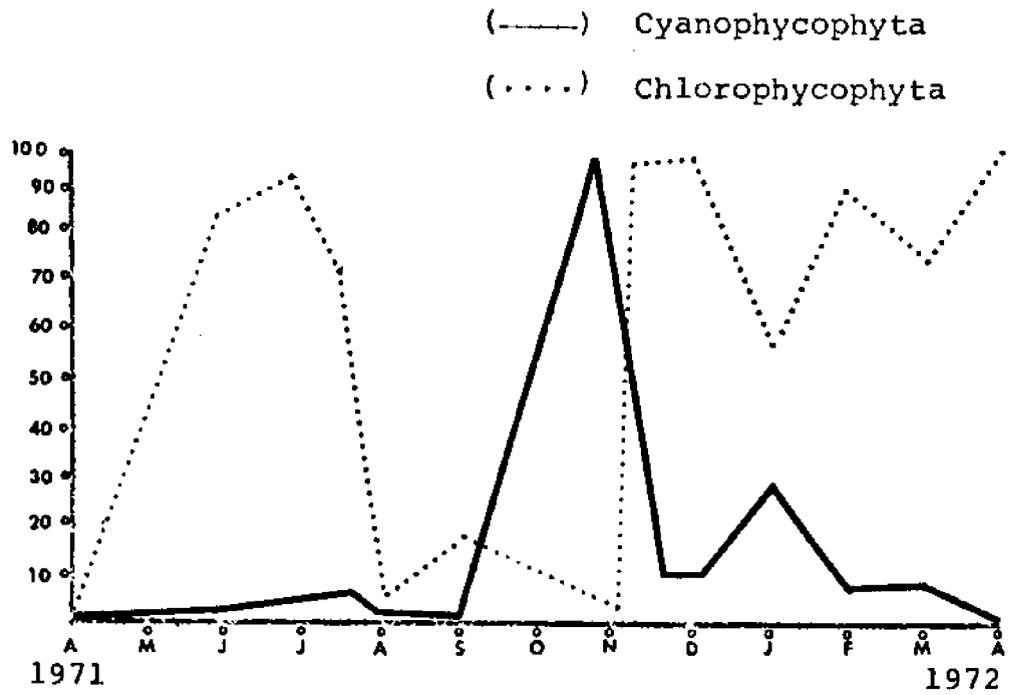


Fig. 5.--Monthly Percentage Composition of Phytoplankton at the Divisional Level in Pond 5 at the Lyman Hatchery.

Scenedesmus (Illust. 37) increased from 63 to 1,463 cells<sup>1</sup> per liter.

The green algae represented by twenty-five algal genera were the dominant algae on twelve of the fourteen collection dates (Table 8, Figure 6). Larger concentrations of the green algae occurred during the winter and spring. Whenever a green algal bloom occurred it was always composed of several different genera. Blue-green and yellow-green algal blooms were usually composed of one alga. Coelosphaerium, Anabaena, Navicula, and Tribonema were the principal blue-green and yellow-green algae which reached bloom proportions (Illust. 59, 65).

Phytoplankton periodicity in the pond was similar to the adjacent channel catfish pond. The green algae were abundant throughout the spring, summer, and winter. The diatoms were abundant during the fall and winter, but were the codominant organisms. The blue-green algae were abundant throughout the fall and increased to maximum concentrations during January (Figure 6).

#### Ole Joe's Catfish Hatchery

Three ponds, utilized for the production of channel catfish, were chosen for investigation at Ole Joe's Catfish Hatchery. Each pond chosen for investigation differed in utilization and fish food application rates, as well as specific differences in phytoplankton production.

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<sup>1</sup>Filaments, colonies, and aggregations of cells recorded as single cells.

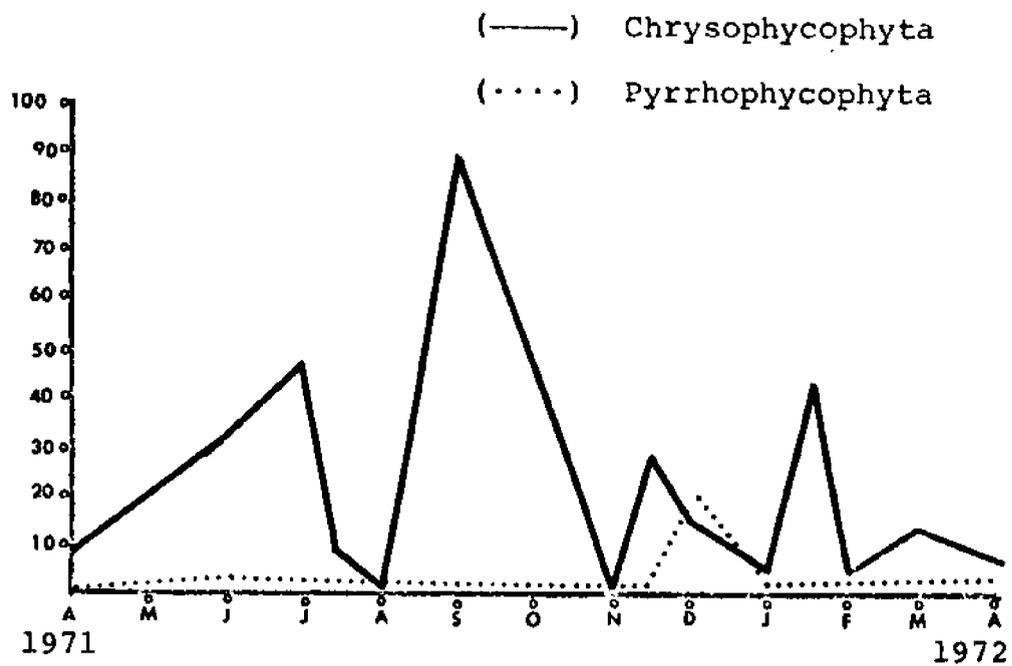
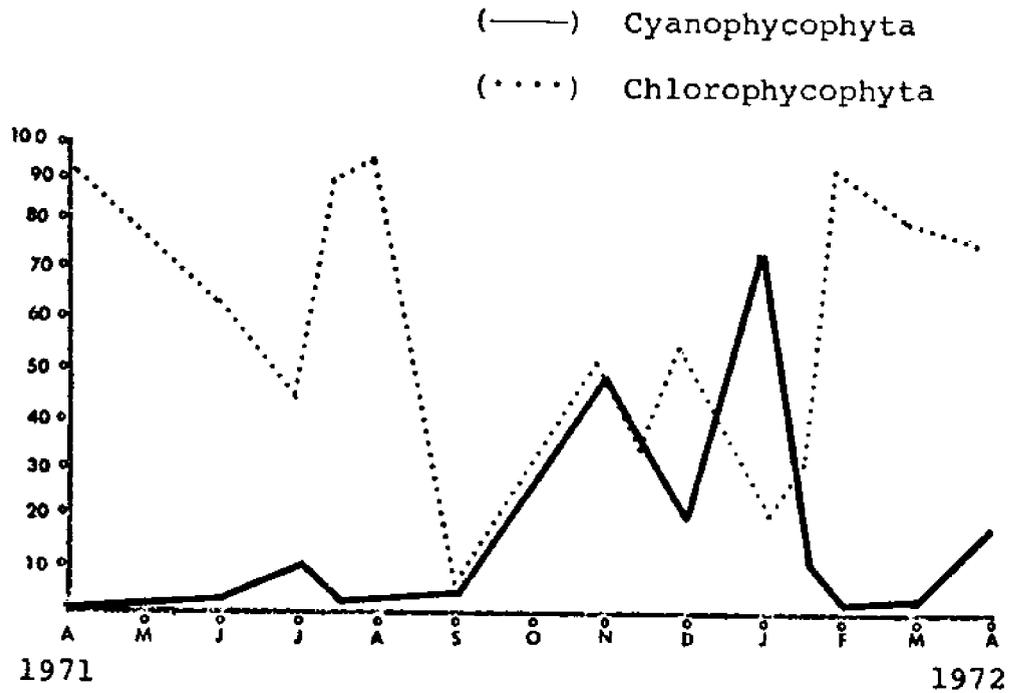


Fig. 6.--Monthly Percentage Composition of Phytoplankton at the Divisional Level in Pond 7 at the Lyman Hatchery.

The Chara and Nitella filled ponds, which were sampled according to the occurrence of the plants, were also included in this section.

Fingerling pond.--This collection site is a channel catfish rearing pond utilized for the production of channel catfish fingerlings. The pond was investigated from May 31, 1971 to April 20, 1972. This pond as well as the brood and feed-out ponds were not chemically treated for the control of aquatic weeds or algae during this study. Also, records of pond production including fish food application rates were not available for this or any other pond investigated at this hatchery.

Algal periodicity in the fingerling pond approximated that of the feed-out and brood ponds, in that the periodicity of each division was confined primarily to the same season of the year (Figures 7-9). Furthermore, algal diversity within the pond was similar to the other ponds with most recorded genera universally present in all the ponds (Table 9). However, the specific differences noted between the three ponds were that the periodicity of a particular genus varied between ponds and the duration and intensity of algal blooms also varied on a generic and divisional basis (Figure 7).

The primary difference between the fingerling pond and other adjacent ponds was that the pond typically

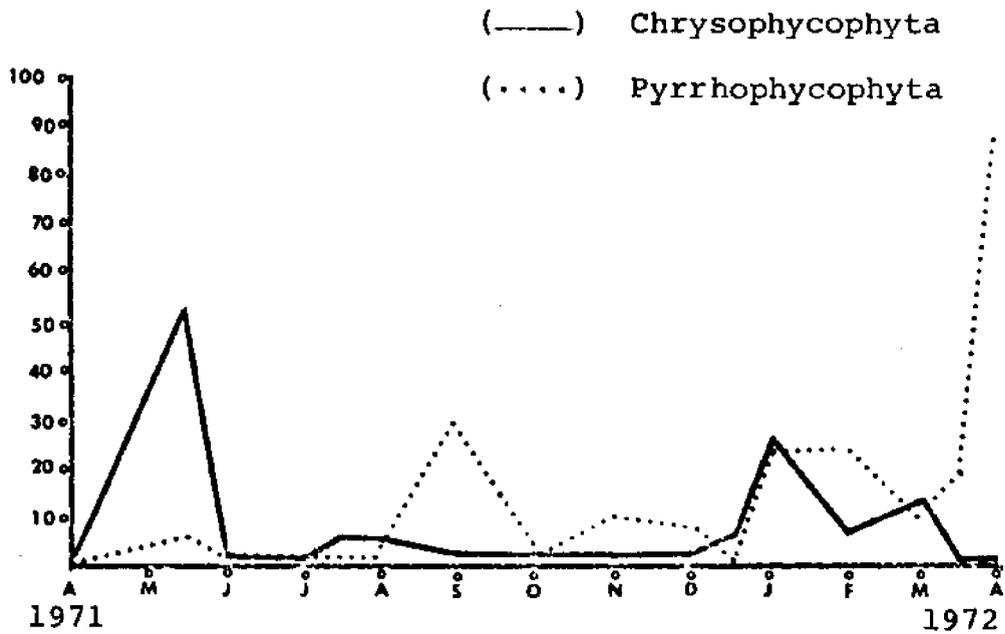
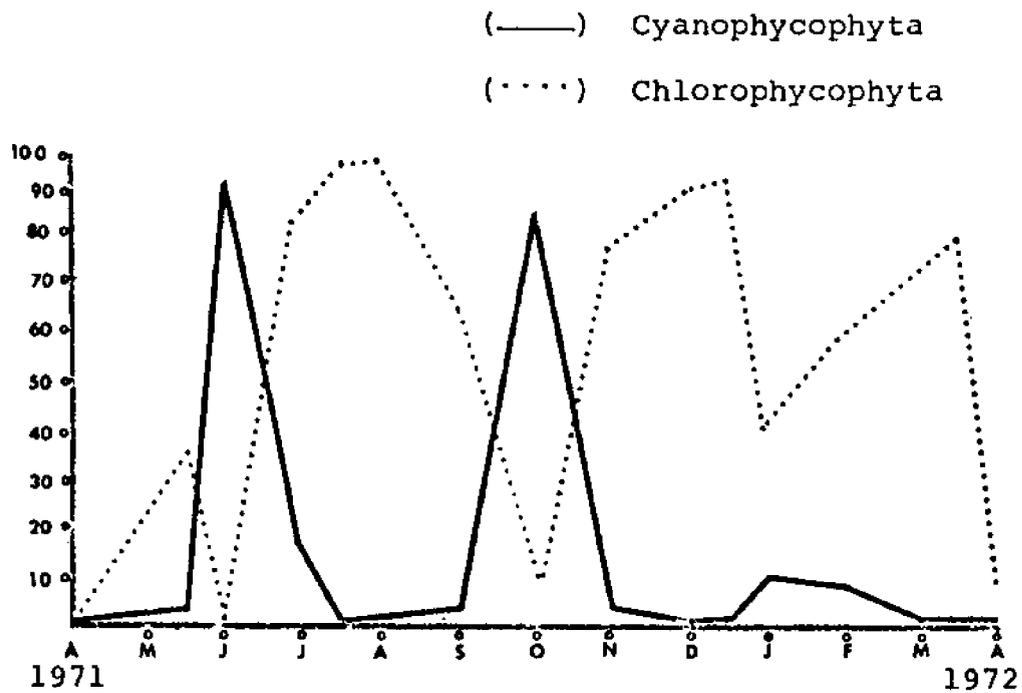


Fig. 7.--Monthly Percentage Composition of Phytoplankton at the Divisional Level in the Fingerling Pond at Ole Joe's Hatchery.

TABLE 9

CUMULATIVE LIST OF ALGAL GENERA AND TOTAL UNITS OF EACH  
GENUS FOUND AT THE LYMAN HATCHERY  
DURING THE SAMPLE PERIOD

	F.O.	F.P.	B.P.
<b>Cyanophycophyta</b>			
<u>Anabaena</u>	2,012	445	2,005
<u>Coelosphaerium</u>	15	277	10
<u>Gleocapsa</u>	NP	NP	56
<u>Gloeotheca</u>	624	NP	NP
<u>Gomphosphaeria</u>	NP	16	NP
<u>Lyngbya</u>	NP	16	NP
<u>Merismopedia</u>	NP	140	2,483
<u>Oscillatoria</u>	1,354	494	NP
<u>Phormidium</u>	65	NP	NP
<u>Polycystis</u>	16,474	4,288	105,757
<u>Unicells</u>	. . .	664	NP
<b>Total</b>	<b>20,544</b>	<b>6,340</b>	<b>110,311</b>
<b>Chlorophycophyta</b>			
<u>Ankistrodesmus</u>	109	28	NP
<u>Chlamydomonas</u>	27	55	134
<u>Closterium</u>	17	244	NP
<u>Closteriopsis</u>	117,631	19,036	87,753
<u>Coelastrum</u>	274	1,958	28
<u>Cosmarium</u>	310	417	NP
<u>Desmidium</u>	100	212	100
<u>Dictyosphaerium</u>	59	789	2,654
<u>Dimorphococcus</u>	222	290	55
<u>Eudorina</u>	262	664	5,326
<u>Eremosphaera</u>	74	NP	29
<u>Euastrum</u>	55	35	54
<u>Filamentous</u>	NP	NP	27
<u>Micrasterias</u>	14	NP	NP
<u>Mougeotia</u>	NP	NP	4,932
<u>Netrium</u>	141	1,019	54
<u>Oedogonium</u>	NP	35	NP
<u>Pandorina</u>	389	106	NP
<u>Pediastrum</u>	2,551	2,174	3,528
<u>Pithophora</u>	NP	NP	35
<u>Pleodorina</u>	NP	NP	279
<u>Radiococcus</u>	NP	55	NP

TABLE 9 (Cont.)

	F.O.	F.P.	B.P.
<u>Scenedesmus</u>	35	181	28
<u>Selenastrum</u>	NP	NP	10
<u>Spirogyra</u>	225	NP	NP
<u>Staurastrum</u>	6,668	4,167	5,066
<u>Tetraspora</u>	NP	445	NP
<u>Ulothrix</u>	8,816	6,094	5,818
<u>Unicells</u>	1,589	9,644	1,416
<u>Volvocalean</u>	NP	106	19
<u>Volvox</u>	221	141	50
<u>Zygnema</u>	NP	63	35
Total	141,808	47,958	117,430
Chrysophycophyta			
<u>Asterionella</u>	NP	NP	308
<u>Cymbella</u>	NP	106	NP
<u>Diatoma</u>	NP	35	NP
<u>Diatoms</u>	366	176	55
<u>Dinobryon</u>	11,102	1,028	8,122
<u>Fragilaria</u>	71	464	20,932
<u>Mallomonas</u>	896	105	1,033
<u>Melosira</u>	380	NP	NP
<u>Navicula</u>	NP	157	NP
<u>Pinnularia</u>	NP	NP	106
<u>Rhizosolenia</u>	NP	28	74
<u>Surirella</u>	NP	52	NP
<u>Synedra</u>	685	63	622
<u>Synura</u>	NP	177	266
<u>Tribonema</u>	426	1,973	6,352
Total	13,926	4,364	37,870
Pyrrhophycophyta			
<u>Ceratium</u>	13,591	9,689	26,203
<u>Peridinium</u>	3,440	2,597	176
Total	17,031	12,286	26,379
Euglenophycophyta			
<u>Euglena</u>	142	123	213
<u>Lepocinclis</u>	NP	125	62
<u>Phacus</u>	106	144	NP
Total	248	392	275

NOTE: NP denotes this particular algae was not present.

Feedout Pond--Algal units compiled from fourteen collection dates.

Fingerling Pond--Algal units compiled from fifteen collection dates.

Brood Pond--Algal units compiled from fourteen collection dates.

had small floating mats of Oedogonium (Illust. 28, 29) located near the bank. These filamentous mats remained throughout the year but were absent from adjacent ponds. In addition to the filamentous mats, the pond differed from other ponds in that the green algae dominated throughout the late summer, fall, and winter. Other ponds had blue-green algal blooms during the summer, or the green and yellow-green algae alternated as the dominant and codominant algae during the summer.

In the fingerling pond, the green algae were the dominant forms on ten of the fifteen collection dates. Two green algae, Coelastrum and Closteriopsis approached bloom conditions and often constituted 90 percent or more of the total plankton. Coelastrum (Illust. 18) occurred primarily during the summer while Closteriopsis (Illust. 16) occurred during the winter and early spring. Coelastrum (also present in other ponds) only approached bloom conditions in the fingerling pond. Closteriopsis frequently reached bloom proportions in all the ponds.

On the initial collection during May, 1971, the yellow-green algae composed 53 percent of the total phytoplankton, but did not compose over 26 percent of the total throughout the remainder of the year. The principal blue-green algae reaching bloom proportions were Gloeothece and Polycystis (Illust. 8, 9) and like the periodicity of blue-greens at Lyman were conspicuous during the summer and late fall.

Feed-out pond.--The collection site called the feed-out pond is a channel catfish rearing pond utilized for the production of channel catfish fingerlings to a size suitable for commercial markets. This pond was investigated from May 5, 1971 through March 7, 1972, but was drained after that time.

Phytoplankton diversity within the feed-out pond approximated that of the adjacent fingerling pond (Table 9) while the periodicity of each division varied both in intensity and occurrence during the year (Figure 8). The chrysophyte Dinobryon (Illust. 56) composed a spring maxima followed by the blue-green algae which dominated throughout the summer. In similar ponds Dinobryon precluded the occurrence of the blue-green algae (Anabaena and Polycystis) during June. In these ponds the blue-greens declined after June and were replaced by the green algae as the dominant forms throughout the summer, fall, winter, and early spring.

During the fall, winter, and early spring Closterio-opsis was the predominant green algae often constituting 50 percent or more of the total plankton. In adjacent ponds the alga constituted a majority of the phytoplankton only during the winter and early spring.

The periodicity of the dinoflagellates and the blue-green algae differed significantly from other ponds.

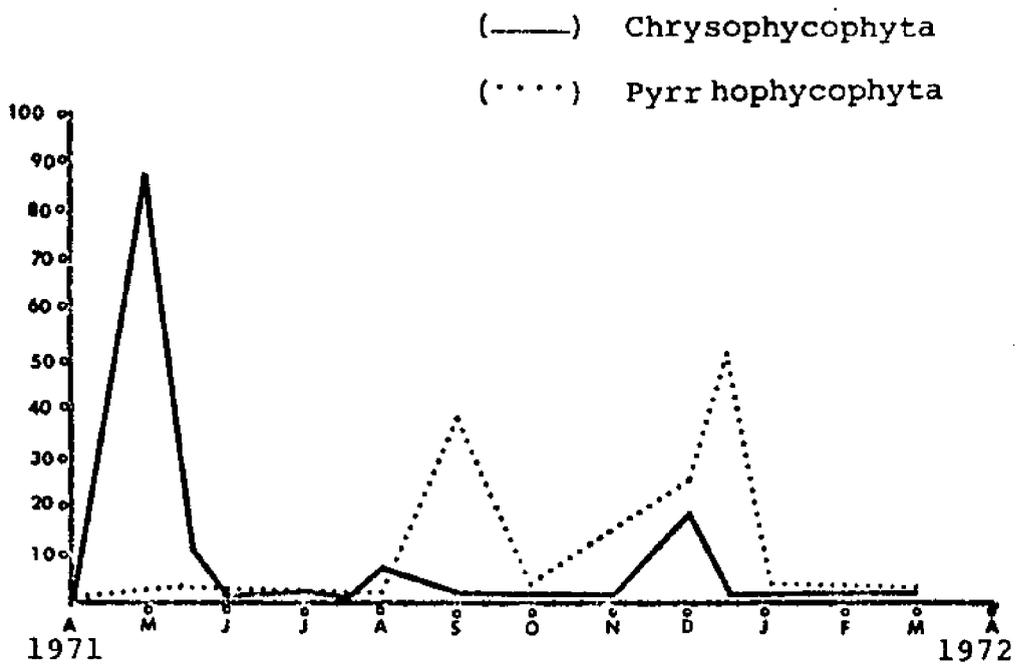
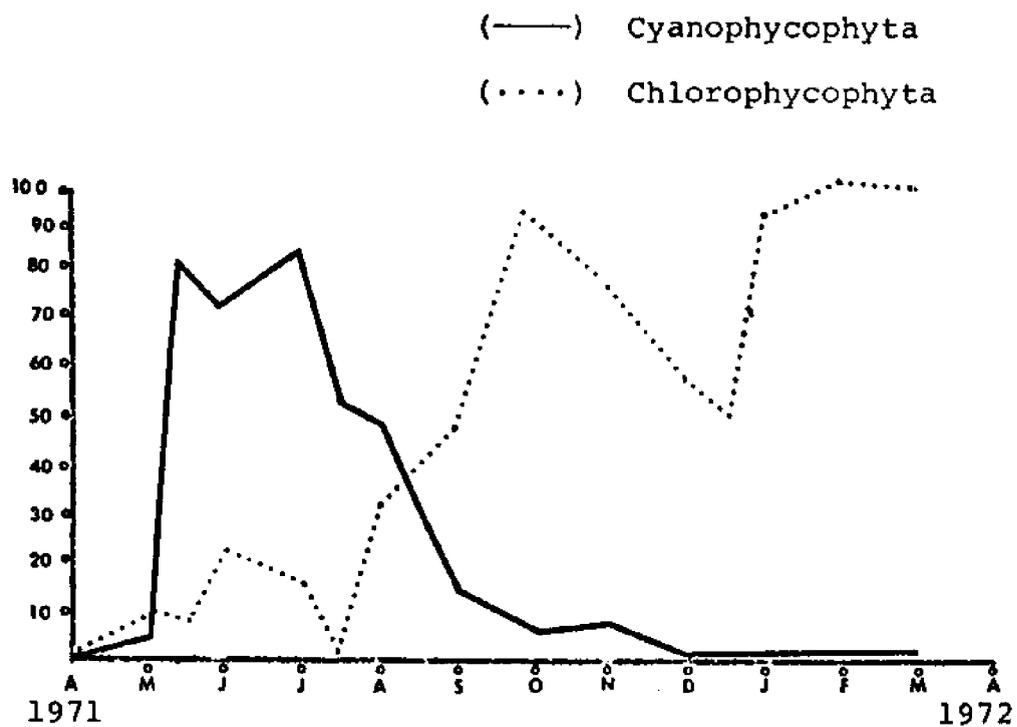


Fig. 8.--Monthly Percentage Composition of Phytoplankton at the Divisional Level in the Feed-Out Pond at Ole Joe's Hatchery.

Ceratium reached maximum concentrations during the spring in most ponds, but was present in bloom proportions during the winter in this pond. The blue-green algae reached maximum concentrations during the fall in adjacent ponds, but composed only 5 to 6 percent of the total at that time in the feed-out pond. Continuing investigations of the pond during the fall and winter of 1972 revealed that the blue-green alga Aphanizomenon flos-aquae (Illust. 3, 4) replaced Closteriopsis and often composed 90 percent or more of the total plankton from September through December. Closteriopsis increased during January and February following the decline of Aphanizomenon in December.

Brood pond.--This collection site is a channel catfish rearing pond which contained selected sexually mature male and female channel catfish. These fish were allowed to breed so that fertilized eggs were readily available for hatching under controlled conditions. The fry obtained through the hatching process formed a basic link in a continuing cycle of fish production at the commercial hatchery.

Regular investigations of this pond began on May 5, 1971 and were terminated on April 20, 1972. The pond contained water from May 5, 1971 through August, 1971 after which time the pond was drained. The pond was dry from September through mid-November, refilled in late November, and subsequently sampled during December.

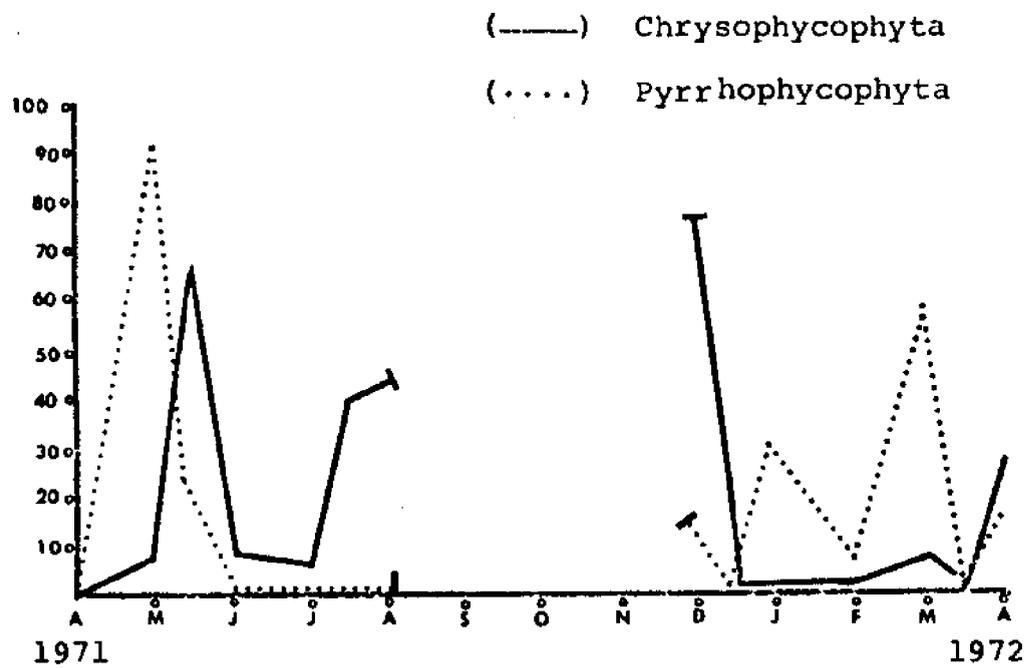
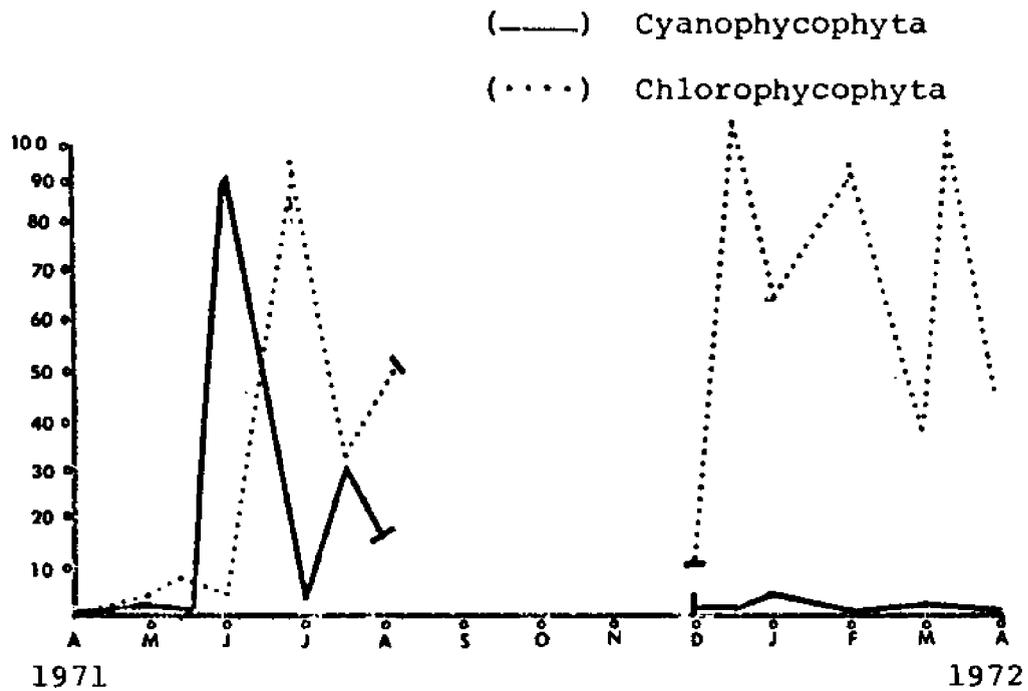


Fig. 9.--Monthly Percentage Composition of Phytoplankton at the Divisional Level in the Brood Pond at Ole Joe's Hatchery.

This pond was the only collection site at either hatchery which had a spring maxima composed of the dinoflagellate Ceratium. The bloom of Ceratium preceded a bloom of Polycystis in June. Following the decline of Polycystis the green algae increased and alternated with the diatoms, as the dominant and codominant algae from July to August.

The blooms of Polycystis and Closteriopsis were composed of more cells per liter than in the other ponds (Table 7). Maximum concentrations of Polycystis occurred during June and July and for Closteriopsis during January and February. Smaller concentrations of Merismopedia, Anabaena, Fragilaria, and Dinobyron occurred intermingled with these blooms.

Chara and Nitella filled ponds.--Three channel catfish rearing ponds containing differing amounts of Chara were investigated during September and October of 1971. These ponds were assigned the numbers one through three with respect to the amount of Chara present in each pond. Pond 1 had approximately 50 percent of the bottom covered by Chara. Ponds 2 and 3 had 25 percent and 10 percent coverage respectively. Also, a channel catfish rearing pond with the bottom completely covered by Nitella was investigated during January, February, and March of 1972.

Plankton analysis of these ponds revealed that phytoplankton diversity as well as total phytoplankton values were directly related to the presence of Chara and Nitella. In the Chara-filled ponds total phytoplankton was inversely proportional to the coverage by Chara. On the September 13 collection, Pond 1 had lower total phytoplankton than either Pond 2 or 3 (Tables 10, 11, and 12). Correspondingly, fourteen algal genera were found in Pond 1, ten in Pond 2, and nine in Pond 3. The lowest total count for the blue-green algae, 68 cells per liter of Polycystis, was recorded for Pond 1. Total blue-green values were higher in Ponds 2 and 3 (Tables 10-12).

The blue-green algae increased in Ponds 1 and 2 after extensive raking virtually eradicated the Chara, although total phytoplankton in Pond 1 was lower than Pond 2 (Tables 10-11, September 24). Approximately three weeks later the plant became reestablished but total coverage was not at previous levels. On the October 18 collection, the blue-green algae were absent and phytoplankton diversity was lower than on the initial collection (Tables 10-11.)

Total net phytoplankton values for the four plant-filled ponds were usually less than the values of adjacent ponds (Tables 10-14, and 5-7). Phosphorus and nitrogen values for the four ponds approximated values of adjacent

ponds (Tables 15, 5-7), and were always adequate (never below 0.015 mg/l) for an algal bloom. Total zooplankton values were not sufficient to account for the reduction of phytoplankton and were reduced as compared with adjacent ponds (Tables 10-14, and 5-7). Therefore, the writer has concluded that phytoplankton production in the Chara-filled pond, and possibly the Nitella-filled pond is related to the production of a growth-limiting substance which directly affects phytoplankton diversity. For instance, several algae such as Volvox, Coelastrum, proboscideum, and Arthodesmus (Illust. 13, 19, 44) were found in abundance in the plant-filled ponds and were either absent or found in small concentrations in adjacent ponds. Closteriopsis, Polycystis, Aphanizomenon, Coelastrum, and other bloom-producers increased as coverage by Chara decreased (Tables 10-12).

TABLE 10

LIST OF ALGAL GENERA AND CONCENTRATION IN UNITS PER LITER  
OF EACH GENUS AND DIVISION FOUND IN A POND  
(CHARA 1) 50 PERCENT COVERED WITH CHARA

	9/13/71	9/24/71	10/18/71	4/20/72
<b>Cyanophycophyta</b>				
<u>Anabaena</u>	. . .	30.6	. . .	. . .
<u>Oscillatoria</u>	. . .	231.3	. . .	. . .
<u>Polycystis</u>	67.5	. . .	. . .	. . .
Total	67.5	261.4	. . .	. . .
<b>Chlorophycophyta</b>				
<u>Closteriopsis</u>	. . .	. . .	. . .	20,022.3
<u>Coelastrum</u>	67.5	. . .	53.1	102.6
<u>Desmidium</u>	30.6	. . .	. . .	. . .
<u>Dictyosphaerium</u>	. . .	135.3	. . .	. . .
<u>Eudorina</u>	67.5	67.5	67.5	. . .
<u>Micrasterias</u>	. . .	30.6	17.1	. . .
<u>Oedogonium</u>	. . .	. . .	1,066.5	. . .
<u>Pediastrum</u>	30.6	168.3	. . .	. . .
<u>Scenedesmus</u>	30.6	. . .	. . .	. . .
<u>Spirogyra</u>	202.5	. . .	. . .	. . .
<u>Staurastrum</u>	30.6	. . .	17.1	. . .
<u>Unicells</u>	30.6	. . .	35.1	. . .
Total	490.5	401.4	1,256.4	124.9
<b>Chrysophycophyta</b>				
<u>Fragilaria</u>	235.8	30.6	. . .	. . .
<u>Nitzschia</u>	. . .	30.6	. . .	. . .
<u>Synedra</u>	30.6	. . .	17.1	. . .
<u>Tabellaria</u>	231.3	. . .	. . .	. . .
<u>Tribonema</u>	. . .	168.3	. . .	. . .
<u>Diatoms</u>	30.6	. . .	. . .	. . .
Total	528.3	229.5	17.1	. . .
<b>Pyrrhophycophyta</b>				
<u>Ceratium</u>	. . .	. . .	. . .	624.6
<u>Peridinium</u>	135.0	. . .	35.1	. . .
Total	135.0	. . .	35.1	624.6

TABLE 10 (Cont.)

	9/13/71	9/24/71	10/18/71	4/20/72
<b>Euglenophycophyta</b>				
<u>Lepocinclis</u>	. . .	. . .	. . .	546.3
Total	. . .	. . .	. . .	546.3
GRAND TOTAL	1221.3	892.8	1308.6	21,295.8

NOTE: Total numbers of Zooplankton were: 9/13/71--129; 9/24/71--76; 10/18/71--156; 4/20/72--216.

TABLE 11

LIST OF ALGAL GENERA AND CONCENTRATION IN UNITS PER LITER  
OF EACH GENUS AND DIVISION FOUND IN A POND  
(CHARA 2) 25 PERCENT COVERED WITH CHARA

FINGERLING POND--CHARA 2

	9/13/71	9/24/71	10/18/71	4/20/72
<b>Cyanophycophyta</b>				
<u>Anabaena</u>	30.6	30.6	. . .	. . .
<u>Aphanizomenon</u>	168.3	2,362.5	. . .	. . .
Total	198.9	2,393.6	. . .	. . .
<b>Chlorophycophyta</b>				
<u>Closteriopsis</u>	1,152.0	62.1	. . .	. . .
<u>Coelastrum</u>	607.5	. . .	17.1	125.1
<u>Eudorina</u>	100.8	135.0	298.8	. . .
<u>Micrasterias</u>	. . .	. . .	35.1	. . .
<u>Netrium</u>	. . .	. . .	. . .	17.1
<u>Oedogonium</u>	. . .	. . .	160.2	. . .
<u>Pediastrum</u>	278.1	. . .	88.2	79.2
<u>Staurastrum</u>	67.5	708.3	17.1	125.1
<u>Ulothrix</u>	231.3	. . .	. . .	62.1
<u>Unicells</u>	675.0	100.8	35.1	. . .
Total	1,960.2	2,096.1	651.6	470.7
<b>Chrysophycophyta</b>				
<u>Fragilaria</u>	67.5	. . .	. . .	. . .
<u>Diatoma</u>	. . .	. . .	35.1	. . .
Total	67.5	. . .	35.1	. . .
<b>Pyrrhophycophyta</b>				
<u>Ceratium</u>	. . .	168.3	. . .	. . .
<u>Peridinium</u>	30.6	1,751.4	372.6	1,133.1

TABLE 11 (Cont.)

	9/13/71	9/24/71	10/18/71	4/20/72
Euglenophycophyta				
<u>Phacus</u>	. . .	. . .	. . .	17.1
<u>Lepocinclis</u>	. . .	. . .	. . .	62.1
Total	. . .	. . .	. . .	79.2
GRAND TOTAL	2,257.2	6,409.4	1,059.3	1,683.0

NOTE: Total numbers of Zooplankton were: 9/13/71--698; 9/24/71--301; 10/18/71--226; 4/20/72--205.

TABLE 12

LIST OF ALGAL GENERA AND CONCENTRATION IN UNITS PER LITER  
OF EACH GENUS AND DIVISION FOUND IN A POND  
(CHARA 3) 10 PERCENT COVERED WITH CHARA

FINGERLING POND--CHARA 3

	9/13/71	4/20/72
<b>Cyanophycophyta</b>		
<u>Aphanizomenon</u>	231.3	26,000.1
Total	231.3	26,000.1
<b>Chlorophycophyta</b>		
<u>Closteriopsis</u>	1914.3	. . . .
<u>Coelastrum</u>	121.5	34.2
<u>Eudorina</u>	121.5	. . . .
<u>Netrium</u>	121.5	. . . .
<u>Pediastrum</u>	. . . .	34.2
<u>Scenedesmus</u>	303.3	. . . .
<u>Staurastrum</u>	2234.7	. . . .
<u>Unicells</u>	1215.0	. . . .
Total	6031.8	68.4
<b>Chrysophycophyta</b>		
<u>Diatoms</u>	121.5	. . . .
Total	121.5	. . . .
<b>Pyrrhophycophyta</b>		
<u>Ceratium</u>	. . . .	308.7
Total	. . . .	308.7
<b>Euglenophycophyta</b>		
<u>Lepocinclis</u>	. . . .	34.2
Total	. . . .	34.2
GRAND TOTAL	6384.6	26,411.4

NOTE: Total numbers of Zooplankton were: 9/13/71--592 and 4/20/72--652.

TABLE 13

LIST OF ALGAL GENERA AND CONCENTRATION IN UNITS PER LITER  
OF EACH GENUS AND DIVISION FOUND IN A POND (CHARA FREE)

FINGERLING POND--ADJACENT, CHARA FREE

	9/13/71	10/18/71	4/20/72
<b>Cyanophycophyta</b>			
<u>Polycystis</u>	270.0	2946.5	. . .
<u>Oscillatoria</u>	. . .	35.1	. . .
Total	270.0	2981.6	. . .
<b>Chlorophycophyta</b>			
<u>Closteriopsis</u>	910.8	. . .	62.1
<u>Coelastrum</u>	33.3	. . .	. . .
<u>Cosmarium</u>	61.2	35.1	34.2
<u>Desmidium</u>	61.2	. . .	. . .
<u>Pediastrum</u>	675.0	248.4	. . .
<u>Scenedesmus</u>	100.8	. . .	17.1
<u>Stauastrum</u>	1695.6	35.1	. . .
<u>Pandorina</u>	. . .	106.2	. . .
<u>Oedogonium</u>	. . .	35.1	. . .
<u>Dictyosphaerium</u>	. . .	. . .	125.1
<u>Eudorina</u>	. . .	. . .	119.7
Total	3537.9	459.9	359.2
<b>Chrysophycophyta</b>			
<u>Fragilaria</u>	100.8	. . .	. . .
<u>Diatoma</u>	. . .	35.1	. . .
<u>Navicula</u>	. . .	17.1	17.1
Total	100.8	52.2	17.1
<b>Pyrrhophycophyta</b>			
<u>Ceratium</u>	. . .	. . .	3499.2
<u>Peridinium</u>	2260.8	. . .	. . .
Total	2260.8	. . .	3499.2

TABLE 13 (Cont.)

	9/13/71	10/18/71	4/20/72
Euglenophycophyta			
<u>Phacus</u>	. . .	71.1	. . .
<u>Lepocincilis</u>	. . .	. . .	125.1
Total	. . .	71.1	125.1
GRAND TOTAL	6169.5	521.0	3999.6

TABLE 14

LIST OF ALGAL GENERA AND CONCENTRATION IN UNITS PER LITER  
OF EACH GENUS AND DIVISION FOUND IN A POND (NITELLA POND)  
100 PERCENT COVERED WITH NITELLA

	1/18/72	2/14/72	3/30/72
<b>Chlorophycophyta</b>			
<u>Arthrodesmus</u>	106	177	. .
<u>Closteriopsis</u>	. .	862	1,490
<u>Closterium</u>	71	142	. .
<u>Cosmarium</u>	71	498	743
<u>Coelastrum</u>	. .	142	106
<u>Desmidium</u>	71	71	317
<u>Euastrum</u>	142	106	106
<u>Eudorina</u>	71	35	1,065
<u>Micrasterias</u>	35	. .	106
<u>Oedogonium</u>	71	. .	. .
<u>Pandorina</u>	142	. .	. .
<u>Pediastrum</u>	71	35	851
<u>Pithphora</u>	. .	106	106
<u>Scenedesmus</u>	. .	. .	. .
<u>Spirogyra</u>	. .	. .	106
<u>Staurastrum</u>	177	862	638
<u>Ulothrix</u>	. .	319	. .
<u>Volvox</u>	1,350	. .	. .
<u>Zygorynchus</u>	142	. .	. .
Total	2,520	3,355	5,634
<b>Chrysophycophyta</b>			
<u>Fragilaria</u>	. .	106	106
<u>Diatoms</u>	. .	177	. .
Total	. .	283	106
<b>Pyrrhophycophyta</b>			
<u>Ceratium</u>	819	35	317
<u>Peridinium</u>	. .	35	. .
Total	819	70	317
<b>Euglenophycophyta</b>			
<u>Euglena</u>	. .	. .	106
Total	. .	. .	106

NOTE: Total numbers of Zooplankton were: 1/18/72--106; 2/14/72--156; 3/30/72--1245.

TABLE 15  
COMPARISON OF THE CHEMICAL AND PHYSICAL DATA  
OF THE CHARA AND NITELLA PONDS

	C-1	C-2	C-3	N.P.	
	9/13/71	9/13/71	1/13/71	2/14/72	3/30/72
<b>Hardness</b> (mg/l)					
Calcium	15	15	30	15	15
Total	15	30	30	30	30
D.O.	8.5	9.2	8.0	7.8	10.2
Temp., °C	30	30	30	12	19
pH	9.6	8.5	8.8	9.2	7.4
<b>Phosphorus</b> (mg/l)					
Ortho	0.090	0.230	0.060	0.290	0.015
Total	0.130	0.290	0.070	0.350	0.090
<b>Nitrogen</b> (mg/l)					
NH <sub>4</sub>	0.45	0.45	0.30	0.37	0.025
NO <sub>3</sub>	0.057	0.057	0.077	0.040	0.920

## CHAPTER IV

### IDENTIFICATION OF THE ALGAE IN HATCHERY PONDS

This section includes the major characteristics of four divisions of the algae, which occurred at the Lyman Hatchery and Ole Joe's Catfish Hatchery in a one-year period beginning in April, 1971 and ending in May, 1972. Six divisions of algae, the Cyanophycophyta, Chlorophycophyta, Charophyta, Chrysophycophyta, Pyrrophyta, and Euglenophycophyta, are described, with the most distinguishing characteristics of each division listed. Photomicrographs and descriptions of the algae which best represented each division and occurred at the hatcheries are included. Within each division the description as well as the photomicrographs of each genus are listed without regard to the classification schemes of the respective division. Notes on field identification and the periodicity of each genus are included. In some cases both field identification and the periodicity (occurrence and significance) of the algae were obtained from managed ponds which are not located at either hatchery. Only ponds with physical and chemical characteristics similar to ponds at the two hatcheries were sampled.

Formal description of the genera used in this thesis can be found in the following references: Smith, 1950; Tiffany and Britton, 1952; Prescott, 1968; Whitford and Schumacher, 1969; and Bold, 1967.

#### Cyanophycophyta (BGA)

The blue-green algae are prokaryotic organisms lacking membrane-bound structures. The pigments include c-phyocyanin, c-phycoerythrin, chlorophyll A, beta-carotene, and two xanthophylls. These pigments are not localized in chromatophores but occur throughout the cell. The photosynthetic, Cyanophyccean starch, does not give a color reaction with IKI.

Heterocysts, unique to the blue-green algae, are present. Flagella are absent on vegetative and reproductive structures. The cells may be free-living, epiphytic, or endophytic. Sexual reproduction is absent while asexual reproduction is by:

Heterocysts: hyaline enlarged cells with two  
polar nodules

Hormogonia: motile chains of cells without a  
sheath

Fragmentation: Accidental breakage of a filament

Akinetes: modified vegetative cells with thickened  
cell walls which resist desiccation.

### Problems Caused by Blue-Green Algae

The blue-green algae are a frequent source of problems in managed ponds. They are notorious as taste and odor producers, filter cloggers, and bloom producers in water supplies including lakes, rivers, streams, and ponds (Palmer, 1959). Certain species can cause additional problems by producing toxins lethal to mammals, birds, and fish (Gentile, 1971; Vance, 1965; Gorham, 1964). In addition, they are not used in the aquatic food chain by other planktonic organisms (Shapiro, 1973; Gentile, 1971). Some blue-green algae may cause changes in pH; Anabaena produces alkaline changes (Palmer, 1959). Swingle (1961) stated that extreme pH levels (4.8-6.0, 9.5-10.5) result in low pond production.

Blooms produced by the blue-green algae are of primary concern to hatchery managers. Water blooms in this area are produced by abundant growths of Polycystis, Anabaena, Aphanizomenon, Lyngbya, Oscillatoria, and several other blue-green algae. These blooms can result in lethal dissolved oxygen concentrations and the subsequent death of fish.

Dissolved oxygen concentrations may be depleted by blooms in several ways: (1) Sunlight, needed for photosynthesis by phytoplankton, may be excluded when blooms form gas bubbles and float to the surface. (2) Several

cloudy overcast days may prevent phytoplankton photosynthesis. Under these conditions respiration may exceed photosynthesis and utilize available oxygen from the water. Additional oxygen depletion may then be caused by bacterial decomposition. The end result is usually lethal dissolved oxygen concentrations.

Should bloom conditions exist, chemical or other control measures may be necessary to prevent fish mortality. However, Palmer (1959) stated that "it is better to anticipate and prevent problems from algae than to delay until they become serious (p. 63)."

#### Identification

The following blue-green algae best represented the principal bloom producing algae which were present during the study. Some of these algae did not reach bloom proportions in the hatchery ponds but were included, since they frequently reached bloom proportions in managed ponds in south Mississippi throughout the spring, summer, and fall, or the early winter, if ambient temperatures remained high.

#### Anabaena

Anabaena, Bory, 1822 (Illust. 1-2, p. 83)

Description.--The filaments may be coiled, contorted, or straight; and may occur as single filaments

or in compact masses. Akinetes and heterocysts are usually present with akinetes formed adjacent to or removed from heterocysts. Each filament is surrounded by a hyaline watery sheath and may be planktonic (free-floating) or attached. Individual filaments are colored blue-green, brown, or blue-black.

Occurrence and significance.--Anabaena (Illust. 1-2) was a common constituent of plankton in hatchery ponds. The alga occurred throughout the year primarily in channel catfish rearing ponds or other ponds where the fish were fed heavily. Maximum concentrations occurred in August but did not exceed 25,000 cells per liter. During winter months cell counts ranged from 100-500 cells per liter.

In ponds where Anabaena constituted 95 percent of the total cells present, the remaining 5 percent consisted of five genera or less. Anabaena, when intermingled with blooms of Polycystis, only constituted approximately 15 percent of the total cells present.

Field identification.--Identification can be made visually or with a good hand lens. Individual filaments within a sample are straight or coiled and colored blue-green or blue-black. These filaments often resemble miniature chains.

Filaments that are dead or deteriorating form additional pseudovacuoles (gas bubbles) and float to the surface forming brown mats. Individual filaments within these mats (scum) feel slimy or slick and break apart easily. The mats often have a damp-earth odor due to associated actinomycetes. Pigments released by the cells color the water a bright blue-green.

### Aphanizomenon

Aphanizomenon, Morren, 1838 (Illust. 3-4, p. 83)

Description.--The filaments of Aphanizomenon are joined throughout their length to form colonies. Each filament within a colony is surrounded by a sheath and may contain both heterocysts and akinetes. The heterocysts and akinetes are cylindrical, although akinetes are longer and not found adjacent to heterocysts. Filaments or colonies of Aphanizomenon are exclusively planktonic.

Occurrence and significance.--Aphanizomenon flos-aquae, as well as the other blue-green algae, was more prevalent during late summer and fall. The largest concentrations occurred in channel catfish rearing ponds where organic loading was heavy. Blooms containing 30,000 cells per liter were not uncommon during spring. Fall concentrations usually exceeded 60,000 cells per liter.

When total counts exceeded 3,000-5,000 cells per liter, a bloom could be expected within two weeks.

Aphanizomenon (Illust. 3-4) was present in concentrations exceeding 30,000 cells per liter from late September through December. Peak concentrations containing 60,000 cells per liter or more occurred during October and November. Total cells per liter declined during December, and the alga was not present in appreciable number during January. Aphanizomenon was present during March and reached maximum spring concentrations (30,000 cells per liter) during April.

Field identification.--Actively growing filaments occur in the water column, but dead or deteriorating cells form gas bubbles and float to the surface to form mats. These mats may be concentrated near the bank by wind-action and are typically blue-green, but may be brown or blue-black. A characteristic musty, fishy, or sewage-like odor may be produced by the mats. Pond water is usually colored dull-green or blue-black.

The colonies of Aphanizomenon feel sticky and like Anabaena break apart easily. The sheath or mucus secreted by the cells is apparently present in greater quantities than Anabaena. The secreted mucilage causes the filaments or colonies to adhere to the walls of plankton nets or

collecting vessels. The macroscopic filaments then give the appearance of freshly cut grass. Colonies when suspended in contained water appear as turfts of hair-like brown grass.

### Lyngbya

Lyngbya, Agardh, 1824 (Illust. 5, p. 83)

Description.--Single filaments may be coiled straight or joined to form clumps. Heterocysts were absent. The filaments may be distinguished from other similar blue-green algae by the clear or yellowish sheath extending beyond the trichome. The sheath is very conspicuous in comparison to the smaller sheath of Oscillatoria (Illust. 7).

Occurrence and significance.--Lyngbya, unlike Anabaena, Aphanizomenon, and Polycystis, (Illust. 1, 3, 5, 8) did not reach bloom proportions in hatchery ponds. The alga occurred during June and July in concentrations ranging from 20-50 cells per liter.

Although not a major bloom causer in hatchery ponds, the alga reached bloom proportions in Lake Jeff Davis, a state-managed lake near Prentiss, Mississippi. Lyngbya formed dense floating mats in the lake. These mats were unsightly and caused additional problems by preventing fishing in some areas of the lake. The mats attached to hooks, fouled plugs or prevented easy access to likely fishing areas.

Field identification.--The presence of black hair-like masses free floating in the water is generally an indication of the genus. Additional visual observation (hold the clumps across the fingers) will reveal the black macroscopic filaments which are difficult to break apart. The clumps frequently smell like freshly-turned soil due to associated actinomycetes.

### Oscillatoria

Oscillatoria, Vaucher, 1803 (Illust. 7, p. 85)

Description.--Planktonic members of this genus are usually found as single filaments, while attached species are found in compact blue-green clumps. Individual filaments are partitioned into cells throughout their length and have little or no sheath present. Single filaments have a forward gliding or side-waving motion, and may be blue-green, blue-black, or variously colored according to the species.

Occurrence and significance.--Abundant growths of Oscillatoria (Illust. 7) did not occur in ponds sampled at the hatcheries. However, the alga did occur throughout the year. Maximum concentrations (500-1500 cells per liter) occurred during October and November. Smaller concentrations (50-400 cells per liter) occurred during June and July.

In general, Oscillatoria was a minor component of the plankton. The organism was usually intermingled with abundant growths of green algae. The algae also occurred in Chara-filled ponds as a minor component (25 percent or less) of the total plankton.

Field identification.--An accurate field identification cannot be made unless the filaments form compact clumps or mats. Even then, a positive identification usually requires microscopic analysis. In some cases, a tentative identification can be made when profuse growths float to the surface and form mats. These growths produce a grassy, musty, or spicy odor (Palmer, 1959). Certain species produce various colors (red, blue-green, black) from phycocyanins and phycoerythrins (Tiffany and Britton, 1952). These pigments when released by dead cells color the water red, blue-green or blue-black. Individual filaments feel slippery, break apart easily, and are often attached to rocks on the bottom of feeder streams and other water sources.

### Polycystis

Polycystis, Kutzing, 1849 (Illust. 8, p. 85)

Description.--Polycystis is a colonial alga with spherical cells enclosed by a hyaline gelatinous sheath. Individual cells have pseudovacuoles present. Colony shape

ranges from oval to ellipsoidal with growth stages exhibiting a wide variety of shapes. Colonies may be colored blue-green, blue-black, or yellowish-green. This organism is similar in appearance to Microcystis, Clathrocystis, and Anacystis.

Occurrence and significance.--Polycystis was the second most abundant blue-green algae. The organism occurred in channel catfish rearing ponds during spring, summer and fall. Profuse growths were usually confined to summer months. Counts during June and July approached 20,000 cells per liter. Fall counts ranged from 3,000-6,000 cells per liter. Polycystis was absent during winter, but reoccurred during mid-April.

During June and July, Polycystis (Illust. 8) formed mats on the pond surface. The mats were usually concentrated near the bank by wind action. Dissolved oxygen concentrations near the surface of the mats approached supersaturation (12-16 mg/l) while concentrations one meter under the surface declined to 3-5 mg/l. Dissolved oxygen concentrations in mat-free portions were usually normal (6-8 mg/l). If physical and/or chemical factors had caused the mats to suddenly die off, lethal dissolved oxygen concentrations could have occurred.

Field identification.--Identification can be made with a good hand lens. The colonies are frequently macroscopic and appear as blue-green or yellow-green clumps.

Waters containing dense growths of Polycystis are usually colored dull-green or brown with a characteristic musty odor. This musty odor resembles an odor produced by duck droppings, or in some cases it may be a fishy odor. The fishy odor seems to be associated with a white film-like covering. This covering is often present where dense mats of Polycystis occur.

#### Merismopedia

Merismopedia, Meyen, 1839 (Illust. 10, p. 85)

Description.--Merismopedia is a plate-like colony one cell layer thick. A sheath surrounds each cell and unites with adjacent cells to form colonies. The colonies are free-floating with cells which lie parallel in two directions.

Occurrence and significance.--Merismopedia (Illust. 10, 11) occurred infrequently in the plankton of hatchery ponds. The alga was present on four sampling dates in a combined total of three ponds, during March, May, July, and August. Merismopedia only constituted 1 to 3 percent of the total plankton in these ponds.

## Illustrations 1-6

## Illust. 1-2

Anabaena

- Illust. 1. Anabaena sp., straight chain filament often found intermingled with blooms of Polycystis, 1100x.
- Illust. 2. Anabaena flos-aquae, typically small filaments with ovoid heterocysts, an alga that may produce toxins, 1100x.

## Illust. 3-4

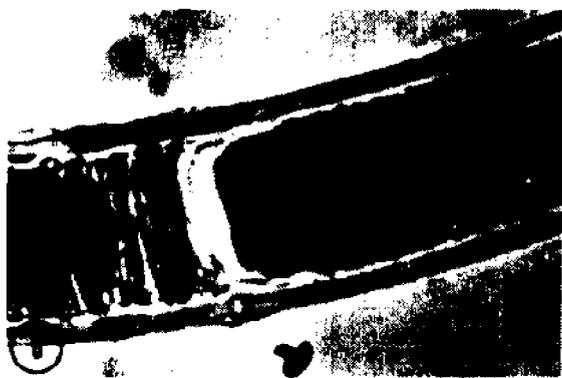
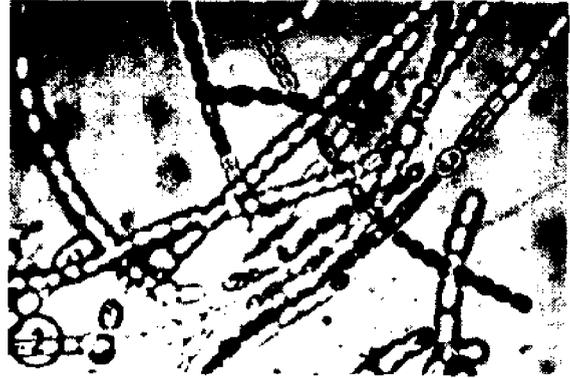
Aphanizomenon

- Illust. 3. Aphanizomenon flos-aquae, an immature colony, notice the cylindrical heterocysts and the attenuated filaments, 126x.
- Illust. 4. Aphanizomenon flos-aquae, large colony, with cylindrical heterocysts, often macroscopic and brown in color, 250x.

## Illust. 5-6

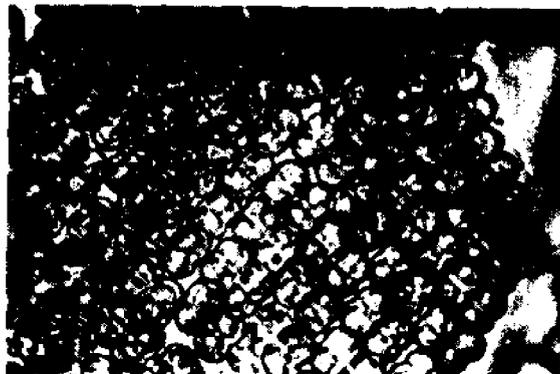
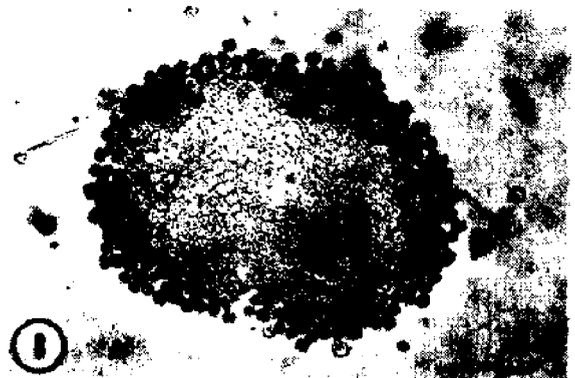
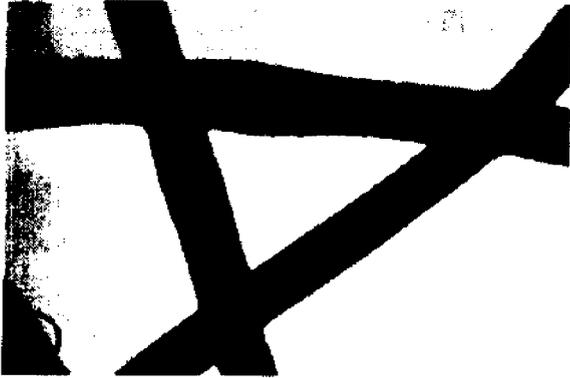
Lyngbya

- Illust. 5. Lyngbya sp., portion of a filament with sheath extending beyond the trichome, 1100x.
- Illust. 6. Lyngbya sp., filament forming hormogonia, which are often black or red in color, 1100x.



## Illustrations 7-11

- Illust. 7. Oscillatoria sp., filaments without an evident sheath and partitioned throughout their length, 390x.
- Illust. 8-9 Polycystis
- Illust. 8. Polycystis sp., growth stage with the spherical cells enclosed by a sheath, 126x.
- Illust. 9. Polycystis sp., compact colony which often has unicellular green algae attached to the outer cells, 126x.
- Illust. 10-11 Merismopedia
- Illust. 10. Merismopedia sp., planktonic colony with the cells dividing in two directions, 125x.
- Illust. 11. Merismopedia convulta, macroscopic alga with tissue-like folds at the margins, 626x.



Field identification.--Accurate identification usually requires microscopic analysis. However, Merismopedia (Illust. 10, 11) may form blanket-like mats below the surface. These mats may be falsely identified and actually be mats of Oscillatoria or Anabaena. Later these algae may reach bloom proportions.

### Chlorophycophyta

The algae included in the division Chlorophycophyta are common known as the grass-green algae. The cells are eukarotic having membrane-bound nuclei, mitochondria, golgi, and plastids. The pigments are localized in chromatophores. The cells contain chlorophyll A and B, which are common in the higher plants, xanthophyll and carotene pigments are present, but are usually masked by the chlorophylls.

Sexual reproduction is present and ranges from isogamy in typical examples like Chlamydomonas (Illust. 14) to oogamy in Oedogonium (Illust. 28, 29). The green algae may also reproduce asexually by:

Zoospores: flagellated asexual cells formed by nonmotile plants.

Akinetes: resistant thick-walled vegetative cells (spores) formed by Pithophora (Illust. 33, 34).

**Aplanospores:** thickened zoospores which have lost their flagella.

**Autocolonies:** asexual reproductive colonies formed by coenobitic algae, e.g., Scenedesmus (Illust. 37).

Collectively the green algae may be unicellular, colonial, filamentous, tubular, or membranous. Unicellular and colonial forms may be motile or nonmotile while some filamentous forms only have flagellated reproductive cells.

The following algae represent green algal body types:

Unicellular forms

Motile: Chlamydomonas (Illust. 14).

Nonmotile: Chlorella (Illust. 15);

Eremosphaera (Illust. 23)

Colonial forms

Motile: Pandorina, Volvox (Illust. 32, 44).

Nonmotile: Pediastrum, Hydrodictyon (Illust. 25, 31).

Filamentous forms

Branched: Pithophora (Illust. 33).

Unbranched: Ulothrix, Oedogonium (Illust. 28, 43).

In addition, the green algae may occur in a wide variety of habitats. They may be found in the air, growing upon or in the soil, and in fresh-water or marine habitats.

Many terrestrial (subaerial) species can be found growing

upon tree trunks, moist rocks, roadside banks, or in other terrestrial habitats. Some species grow only upon snow.

#### Green Algae as Friend or Foe?

Planktonic green algae, if present in relatively small numbers, are considered beneficial organisms in hatchery ponds. Even when present in bloom proportions they are often considered beneficial components of the aquatic ecosystem in a hatchery pond (Snow et al., 1964). The green algae are also utilized as a food source by rotifers and crustaceans (Pennington, 1941; Pennack, 1946; Edmonson, 1965). In turn the rotifers and crustaceans are utilized as food by fish larvae. Therefore, the green algae are considered to be a basic link in the aquatic food chain (Prescott, 1968). Some researchers have reported that the algae are utilized as a direct food source by fish (Zarnecki, 1967). However, these fish were primarily asiatic carp, Israeli carp, or other similar species not commonly grown on a commercial basis in the United States.

Due to their beneficial characteristics, blooms of green algae are often promoted by pond fertilization (Henderson, 1949). Commercial grade 8-8-2 (100 lb. bag contains 8 percent nitrogen, 8 percent phosphorus, and 2 percent potassium) fertilizer applied at a rate of 100 pounds per acre every two to four weeks during the summer months promotes phytoplankton blooms (Snow et al., 1964;

Smith and Swingle, 1939). These blooms help suppress the growth of aquatic weeds and other undesirable forms, i.e., blue-green algae. As an indirect result fertilization increases fish production in ponds (Swingle, 1963; Henderson, 1949; Swingle, 1945; Smith and Swingle, 1939).

The primary offenders among the green algae are those filamentous algae which frequently form dense mats on the pond surface. Some of the more common mat-forming green algae are Pithophora, Hydrodictyon (water net, actually a nonmotile colonial form), Ulothrix, Oedogonium, and Spirogyra (Illust. 33, 25, 43, 28, 38). Mats formed by these algae are responsible for substantial decreases in total fish production.

Mats formed by filamentous green algae trap and suffocate young fry during fish harvesting operations. In some cases the mats may prevent fish harvesting until the mats have been removed from the pond. Indirectly the mats decrease fish production by reducing total phytoplankton or preventing complete utilization of fish food pellets (Snow, 1964). In addition, ponds containing the dense mats cannot be used to full capacity since 50 to 75 percent of the total surface area may be covered. Dissolved oxygen concentrations in ponds where the surface is totally or partially covered, are usually at lethal limits beneath the mats (Gasaway, 1962).

Other non-filamentous green algae may occasionally be nuisance organisms in hatchery ponds. Numerous green algae Chlamydomonas, Chlorella, Ankistrodesmus (Illust. 12, 14, 15) to name a few are capable of producing blooms (Palmer, 1959). However, blooms of the green algae rarely cause oxygen depletion or produce toxins as do blue-green algal blooms. The green algae are primarily taste and odor producers or filter cloggers or they produce unsightly mats or blooms in water supplies (Palmer, 1959).

#### Ankistrodesmus

Ankistrodesmus, Corda, 1838 (Illust. 12, p. 112 )

Description.--The cells may be criss-crossed, occur in clumps or as single cells. Individual cells are needle-like, without a gelatinous covering, and gradually taper to a point. The cells of Ankistrodesmus resemble the cells of Closteriopsis, but the former may be differentiated by the presence of a single laminate chloroplast and the shorter length (never over 6  $\mu$ ) of the cells.

Occurrence and significance.--Ankistrodesmus (Illust. 12) was an alga of infrequent occurrence in hatchery ponds. The occurrence of Ankistrodesmus was confined primarily to spring and summer months with concentrations approaching 10,000 cells per liter during

July. Smaller concentrations of 50-100 cells per liter occurred during November and early December.

Prescott (1968) stated that Ankistrodesmus was on occasion a pest in fish ponds; and Palmer (1959) listed the organism as a bloom causer in water supplies.

Field identification.--None.

### Arthrodesmus

Arthrodesmus, Ehrenberg, 1838 (Illust. 13, p. 112)

Description.--The cells of this desmid are often indistinguishable between certain species of Staurastrum and Xanthidium. However, this alga can be identified by the thick gelatinous sheath surrounding the cell, the deeply constricted cells, and the small curved spines on the periphery of the cell.

Occurrence and significance.--Arthrodesmus (Illust. 13) was a common constituent of plankton in ponds containing dense growths of Eleocharis (an aquatic angiosperm), and Nitella, but did not occur in Chara-filled ponds. In Eleocharis and Nitella-filled ponds, the alga was more prevalent during January and February. Arthrodesmus never constituted over 5 percent of the total plankton in these ponds.

Field identification.--None.

Chlamydomonas

Chlamydomonas, Ehrenberg, 1833 (Illust. 14, p. 112)

Description.--The cells of this unicellular volvocalean alga may be spherical, round, or variously shaped and may contain a red eyespot. Two whiplash flagella are present on the anterior end of the cell. The chloroplast within the cell may be cup-shaped, H-shaped, or stellate.

Occurrence and significance.--Chlamydomonas (Illust. 12) occurred sporadically during late spring, summer, and fall in hatchery ponds. Maximum concentrations did not exceed 600 cells per liter. Therefore, it appears that the alga did not reach bloom proportions throughout the year.

Field identification.--Abundant growths of Chlamydomonas produce a musty, grassy, fishy, or septic odor, and often give the water a slick touch sensation (Palmer, 1959). These odors, however, may be produced by other algae making accurate field identification impossible unless substantiated by microscopic analysis.

Chlorella

Chlorella, Beijerinck, 1890 (Illust. 15, p. 112)

Description.--The cells of this coccoid green alga are non-motile without pyrenoids, and have a cup-shaped or band-like chloroplast. The cells are usually 5-10  $\mu$  in diameter.

Occurrence and significance.--Chlorella (Illust. 15) was not present in large numbers in analyzed net samples. The organism occurred in Ponds 3 and 7, July 23, 1971. Cell counts in the two ponds were 90 and 217 cells per liter respectively.

A dense bloom of Chlorella which passed through the net a nannoplankton was present at the Lyman Hatchery March 16, 1972. Hatchery personnel had applied copper sulfate the previous day and the bloom appeared to be subsiding.

Field identification.--Water containing dense blooms of Chlorella has a musty odor (Palmer, 1959) and is colored bright green.

### Closteriopsis

Closteriopsis, Lemmermann, 1898 (Illust. 16, p. 112)

Description.--The cells of Closteriopsis are needle-like, typically straight, and without a gelatinous covering. The chloroplast is regularly interrupted along the cell wall by twelve or more pyrenoids. Closteriopsis may be differentiated from Ankisthodesmus (Illust. 9) by its longer length.

Occurrence and significance.--Closteriopsis longissima (Illust. 16) was a major bloom causer at Ole Joe's Hatchery, but occurred infrequently and in small concentrations at the Lyman Hatchery. At Ole Joe's, dense concentrations occurred during late fall, winter, and early spring. Fall concentrations ranged from 1,000-2,000 cells per liter. During December, January, February, and March cell counts reached maximum concentrations of 20,000 to 40,000 cells per liter. After maximum concentrations in March, the alga declined during April and was not present during the summer.

Field identification.--The cells of Closteriopsis are macroscopic and when present in dense concentrations superficially resemble the blue-green alga Aphanizomenon flos-aquae (Illust. 3). Both Aphanizomenon and Closteriopsis produce a pronounced fishy odor when present in abundance. By comparison Closteriopsis colors the water bright green or yellow-green while Aphanizomenon produces a blue-green, blue-black, or brown colored water.

### Closterium

Closterium, Nitzsch, 1817 (Illust. 17, p. 112)

Description.--The cells are regularly curved, flexed, or straight, and without a median constriction. Single cells are divided into two semicells each with one chloroplast. The semicells have a broadly rounded

pole with pyrenoids evenly or axially distributed. The cell wall may be brown or yellow brown.

Occurrence and significance.--Normally cell counts for Closterium (Illust. 17) ranged from 20-200 cells per liter, but the July counts were considerably higher approaching 2,350 cells per liter. Otherwise, Closterium was not a bloom causer in sampled ponds at the two hatcheries.

Field identification.--Closterium and several other desmids when present in large concentrations tend to aggregate or clump below the water surface. While certain species of Closterium are macroscopic and can be identified with a hand lens, others are smaller and require microscopic analysis.

#### Coelastrum

Coelastrum, Naegeli, 1849 (Illust. 18, 19, p. 114)

Description.--The cells of this coenobitic alga are compacted with individual cells forming a hollow sphere of 4, 8, 16, 32, or 128 cells. Individual cells may be smooth, spiny, or have tube-like projections. The chloroplast may be cup shaped or cover the entire cell.

Occurrence and significance.--Coelastrum sp. (Illust. 18) was present in concentrations ranging from 1,000 to 8,000 cells per liter during July and August.

Cell counts declined (30 to 150 cells per liter) during fall and the alga was not present by December. Coelastrum reoccurred during March and April, but did not occur during the summer.

Coelastrum proboscideum (Illust. 18) occurred in Chara and Nitella-filled ponds in concentrations ranging from 30 to 600 cells per liter but was absent in plant-free ponds.

Field identification.--None.

#### Cosmarium

Cosmarium, Corda, 1834 (Illust. 20, p. 114)

Description.--The cells of this desmid have a deep median constriction which divides the cells into two identical halves (semicells). Each semicell, depending on the species, may have one, two, or four chloroplasts. Individual cells may be round or slightly longer than broad.

Additionally, the outer cell wall may be smooth or rough.

Occurrence and significance.--Cosmarium (Illust.20) occurred in maximum concentrations during June, July, and August. Counts approaching 22,000 cells per liter were recorded for July. Minimum concentrations (30-750 cells per liter) occurred during spring, winter, and fall. Cosmarium was not normally present in abundance, but the abnormally high July counts indicate that the organism may occasionally be troublesome.

Field identification.--None.

Eudorina

Eudorina, Ehrenberg, 1832 (Illust. 22, p. 114 )

Description.--The biflagellated cells of this volvocalean alga are enclosed by a hyaline gelatinous matrix and may be near or removed from the margin of the matrix. The flagella protrude from the matrix and are two to four times the length of the cell. The colonies may contain 16, 32, or 64 cells.

Occurrence and significance.--Maximum concentrations containing 5,000 to 15,000 cells per liter occurred during June and July. Minimum concentrations of 100 to 1,000 cells per liter occurred during fall (September, October) and winter (December, January). Maximum concentrations occurred where aquatic macrophytes and/or filamentous algae (Hydrodictyon, Pithophora) were actively growing.

Field identification.--A characteristic fishy odor is produced by dense concentrations of Eudorina (Palmer, 1959). However, field identification is usually difficult since Pandorina and Volvox also produce a fishy odor.

Eremosphaera

Eremosphaera, De Bary, 1858 (Illust. 23, p. 114 )

Description.--The cells are non-motile, thin-walled, and typically larger than other unicellular green algae. The discoid chloroplasts radiate in a reticulum-like meshwork. The nucleus is embedded in the center of the cell by cytoplasmic strands.

Occurrence and significance.--Cell counts ranged from 30 to 800 cells per liter during May, June, and July. During October and November the counts were from zero to forty cells per liter.

Field identification.--None.

#### Euastrum

Euastrum, Ehrenberg, 1832; emend., Ralfs, 1844  
(Illust. 24, p. 116 )

Description.--The cells are deeply constricted with a length usually twice the width. Each semicell is truncate-pyramidal in shape, and with a smooth or rough outer wall.

Occurrence and significance.--Euastrum (Illust. 24) is probably never a major component of phytoplankton in hatchery ponds. The organisms occurred predominantly during the winter and were occasionally present in the summer. Total counts ranged from 10 to 150 cells per liter.

Field identification.--None.

Hydrodictyon

Hydrodictyon, Roth, 1800 (Illust. 25, p. 116)

Description.--The macroscopic cells are united into a net-like coenobium with the chloroplast reticulate in young cells and diffuse in older cells. The presence of the nets formed by young and mature cells readily identifies this alga. Typically five to six cells form the ring-like nets.

Occurrence and significance.--Hydrodictyon (Illust. 25) became established during late March in a bass-bluegill rearing pond at the Lyman Hatchery. The first mats appeared in April, covered approximately 25 to 40 percent of the total surface area, and remained until late November. Several adjacent ponds were totally covered by the alga. Hydrodictyon only occurred in ponds with the water pH 7.1 or above.

Water level fluctuation and chemical treatment with copper sulfate was initiated by hatchery personnel in an attempt to control the profuse growth in Pond 1. However, these methods were unsuccessful and the mats remained at previous levels throughout the summer. In fact, a dense bloom of Anabaena occurred after two successive copper sulfate treatments.

Field identification.--Hydrodictyon has a coarse-sandy touch sensation. The ring-like nets of mature cells are macroscopic and readily identified the alga.

### Kirchneriella

Kirchneriella, Schmidle, 1893 (Illust. 26, p. 116)

Description.--The cells are moderately curved or flexed with rounded apices. Individual cells which may be crescent-shaped are grouped into four or more cells surrounded by a gelatinous matrix.

Occurrence and significance.--Kirchneriella (Illust. 26) was present during spring and summer in concentrations ranging from 10 to 1,000 cells per liter. Fall counts consisted of 10 to 40 cells per liter. Total plankton counts indicate the Kirchneriella was a minor component of the plankton.

Field identification.--None.

### Micrasterias

Micrasterias, Agardh, 1827 (Illust. 27, p. 116)

Description.--The cells are flat bilaterally symmetrical, and slightly longer than broad. The cells are deeply constricted forming semicells with one polar lobe and two to four lateral lobes.

Occurrence and significance.--Micrasterias

(Illust. 27) was a minor component of the plankton in hatchery ponds. Cell counts ranged from 10 to 100 cells per liter throughout the year.

Field identification. None.

Oedogonium

Oedogonium, Link, 1820 (Illust. 28, p. 116)

Description.--This unbranched filamentous alga can be identified by the transverse striations on the cell wall, and the unevenly distributed pyrenoids within the cell. Filaments of Oedogonium may reproduce vegetatively or sexually. Atheridia and oogonia are present in sexually reproducing filaments.

Occurrence and significance.--Vegetative filaments of Oedogonium (Illust. 28) were usually free-floating or aggregated to form small floating mats. Profuse growths did not occur in hatchery ponds.

The alga occurred throughout the year in small quantities attached to sticks, rocks, or other objects near the pond bank. Only vegetative filaments were encountered.

Field identification.--Vegetative filaments of Oedogonium are coarse string-like, and superficially resemble the filaments of Spirogyra (Illust. 38). Filamentous

mats of Oedogonium pull apart like cotton while the filaments of Spirogyra break apart easily.

### Pachycladon

Pachycladon, Smith, 1924 (Illust. 31, p. 118)

Description.--The cells are usually round with four brown appendages. The chloroplast is cup-shaped and contains a singly pyrenoid. A red dot is present in the centrally located pyrenoid.

Occurrence and significance.--Pachycladon occurred during September, October, and November in concentrations from 5 to 50 cells per liter. This organism also occurred in several ponds unrelated to this research, and was consistently a minor component of the plankton.

Field identification.--None.

### Pediastrum

Pediastrum, Meyen, 1829 (Illust. 32, p. 118)

Description.--The cells of this coenobitic alga are closely appressed forming flat colonies one cell layer thick. Outer cells of the colony differ from inner cells by the presence of spines or tube-like projections on the former. The cell wall may be smooth or rough.

Occurrence and significance.--Pediastrum (Illust. 31) occurred throughout the year with maximum concentrations of

2,000 to 5,000 cells per liter occurring in July and August. Cell counts usually increased from minimum concentrations in February to concentrations approaching 1,000 cells per liter during April, May, and June.

Field identification.--Abundant concentrations of Pediastrum produce a grassy odor (Palmer, 1959). When concentrations approach 5,000 cells per liter, the cells of Pediastrum clump and settle to the bottom of collecting vessels.

#### Pandorina

Pandorina, Bory, 1824 (Illust. 30, p. 118)

Description.--The colonies of Pandorina have 4, 8, 16, or 32 closely packed cells embedded within a hyaline gelatinous matrix. Individual cells have two flagella protruding from the margin of the matrix. Each cell contains a cup-shaped chloroplast.

Occurrence and significance.--Pandorina (Illust. 32) was not a bloom causer in hatchery ponds. The alga occurred primarily during September, October, and November. Total counts did not exceed 1,500 cells per liter.

Field identification.--None.

Pithophora

Pithophora, Wittrock, 1877 (Illust. 33, p. 118 )

Description.--The filaments of Pithophora are regularly branched with rhizoid-like branches occurring on the basal portion of the cell or at the cell tip. Akinetes are present and formed at the terminal end of the branches.

Occurrence and significance.--Pithophora (Illust. 33, 34) was a major problem causer in hatchery ponds. Profuse growths occurred in alkaline waters (pH 8.0-9.5). The alga was more abundant during summer and fall often covering 50 percent or more of the pond surface. Pithophora occurred primarily in channel catfish rearing ponds where organic nutrient levels were increased by fish foods or other organic compounds. Significant reductions in total phytoplankton occurred in the ponds infested with Pithophora. Other factors which cause decreases in total fish production have been discussed previously.

Field identification.--The filaments are coarse cotton-like and generally have black macroscopic akinetes. If the filaments of Pithophora lack akinetes, they may be confused with Oedogonium or Rhizoclonium. Akinete formation can be induced by placing an adequate sample of Pithophora in a sealed container for three or four days.

Platydorina

Platydorina, Kofoid, 1899 (Illust. 35, p. 118 )

Description.--Either 16 or 32 cells are enclosed by a gelatinous matrix to form a horseshoe-shaped colony. Individual cells are biflagellated, have discoid chloroplasts, and a red eye spot.

Occurrence and significance.--Platydorina (Illust. 35) was the rarest volvocalean occurring in hatchery ponds. The alga only occurred during the summer in concentrations of fifty cells per liter or less.

Field identification.--None.

Pleodorina

Pleodorina, Shaw, 1894 (Illust. 36, p. 120 )

Description.--The colonies may contain 32, 64, or 128 cells. Individual cells within a colony may be vegetative or reproductive which divides the colony into a vegetative and a reproductive portion.

Occurrence and significance.--Pleodorina (Illust. 36) occurred during June and July in concentrations ranging from 40 to 300 cells per liter.

Field identification.--None.

Scenedesmus

Scenedesmus, Meyen, 1829 (Illust. 37, p. 120 )

Description.--The cells of this coenobitic alga are joined in multiples of two consisting of 4, 8, or more cells. The cell wall may be smooth, ornamented, or have straight or curved spines. Cells within the coenobium are not replaced if destroyed. Therefore, coenobium containing 3, 5, or other odd numbers may occur.

Occurrence and significance.--Scenedesmus (Illust. 37) occurred throughout the year usually in small concentrations. A summer maxima consisting of 1,000 to 4,000 cells per liter occurred during July and August.

Field identification.--None.

Spirogyra

Spirogyra, Link, 1820 (Illust. 38, p. 120)

Description.--This filamentous alga may be identified by the presence of one, two, or several spiral-shaped chloroplasts within the cells of vegetative filaments. Sexual reproduction may occur by lateral or sclariform conjugation to form thick-walled zygotes.

Occurrence and significance.--Filaments of Spirogyra (Illust. 38) were found in drainage ditches, ponds, or practically any small depression capable of holding water. The alga occurred throughout the year.

Spirogyra formed mats near the bank during early spring and summer. Later these mats became free floating, but did not cause significant problems in the ponds.

Field identification.--The filaments of Spirogyra feel slimy or slick to the touch. They are thread-like, unbranched, and break apart easily. Actively growing filaments are bright green while sexually reproducing filaments are yellow-green. Palmer (1959) stated that abundant growths of Spirogyra produce a grassy odor.

#### Staurostrum

Staurostrum, Meyen, 1829 (Illust. 39-41, p. 120 )

Description.--The cells of this desmid are usually bilaterally symmetrical (Illust. 39) but may have several different shapes according to the species. The cells are always deeply constricted forming two semicells with an axial chloroplast in each half. The cell wall may be smooth, rough, or have indentations along the margin. Certain species may have spiny cell walls.

Occurrence and significance.--Staurostrum (Illust. 39) was the most commonly occurring desmid in hatchery ponds. Practically any one plankton sample taken at the two hatcheries had one or more species of Staurostrum present (Illust. 40, 41).

The alga was present at one time or another in all ponds sampled. Staurastrum (Illust. 39) occurred predominantly during the summer. Total cell counts for the species exceeded 31,500 cells per liter during July. Cell counts increased from fifty cells per liter during April and May to 1,000 cells per liter during June. Cell counts for fall and winter ranged from 50 to 500 cells per liter.

Field identification.--None, other than a characteristic grassy odor produced by abundant concentrations (Palmer, 1959).

#### Tetraedron

Tetraedron, Kutzing, 1845 (Illust. 42, p. 122)

Description.--The cells may be flat or angular with a wide variety of shapes. The chloroplast may be parietal or cover the entire cell. The cell wall may be smooth or rough with eight extensions of the cell, subdivided to form sixteen spines or protrusions. In some species the extensions are entire.

Occurrence and significance.--Tetraedron sp. occurred only once during the sampling period. In all probability, this organism was not a major component of the phytoplankton in hatchery ponds. However, other members of the Oocystaceae (Chlorella, Ankistrodesmus) were important components of the plankton in hatchery ponds.

Field identification.--None.

### Ulothrix

Ulothrix, Kuetzing, 1833 (Illust. 43, p. 122)

Description.--The filaments are unbranched and contain a bracelet-shaped chloroplast with one or more pyrenoids. Mature cells are often free-floating while young cells are attached to a substratum by a basal hold-fast cell.

Occurrence and significance.--In some cases Ulothrix zonata may form dense floating mats (Johnson, 1955). However, Ulothrix sp. (Illust. 43) did not occur in concentrations sufficient to form mats. The alga occurred in hatchery ponds during November, December, January, February, March, and April. Cell counts did not exceed 2,500 cells per liter and normally ranged from 100 to 500 cells per liter.

Field identification.--None.

### Volvox

Volvox, Linnaeus, 1758 (Illust. 44, p. 122)

Description.--The colonies of Volvox can be differentiated from other similar volvocaleans by their larger size and the large number of cells (500-50,000) within the colonies. The colonies are globose or oval with small biflagellated cells. The flagella protrude

from the matrix. In addition, the colonies may contain zygotes, daughter colonies or may be vegetative.

Occurrence and significance.--Volvox (Illust. 44) was the dominant alga in a channel catfish fingerling pond filled with Nitella. This pond was characterized by the absence of blue-green algae and the predominance of green algae and diatoms. Cell counts for Volvox in this pond ranged from 40 to 1,200 cells per liter.

Volvox was present in adjacent ponds, but was a minor component of the plankton.

Field identification.--This alga if present in abundance can be visually identified. Colonies of Volvox when present in plankton samples give the appearance of net-like miniature balls and aggregate near the surface.

#### Xanthidium

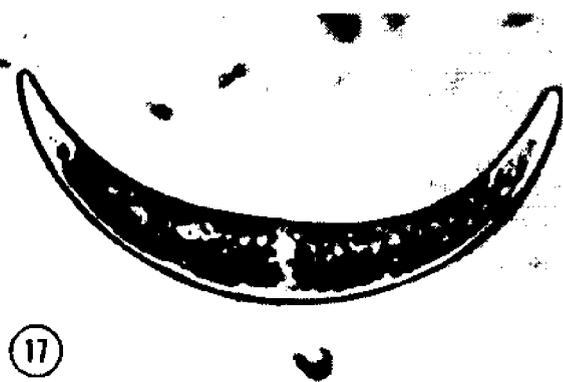
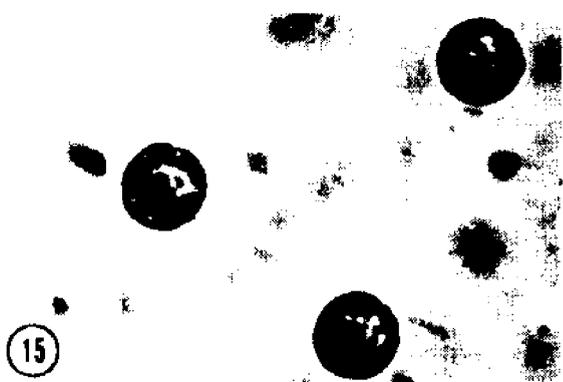
Xanthidium, Ehrenberg, 1837 (Illust. 45, p. 122)

Description.--The cells of Xanthidium resemble the cells of Arthrodesmus (Illust. 13). However, they can be separated by the lack of a definite sheath in Xanthidium and the compound spines on the periphery of the cell.

Occurrence and significance.--Xanthidium (Illust. 45) was one of the rarest desmids that occurred in hatchery

## Illustrations 12-17

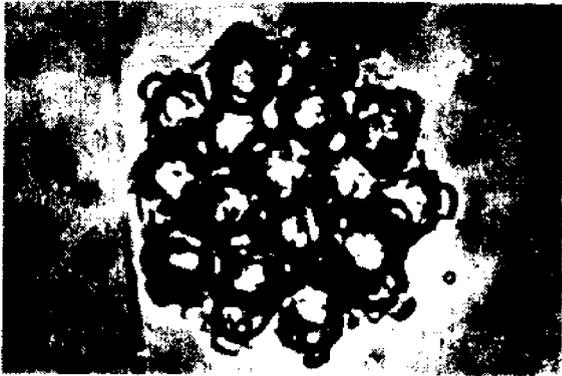
- Illust. 12. Ankistrodesmus falcatus, needle-like cells which may be criss-crossed or occur as single cells, 500x.
- Illust. 13. Arthrodesmus sp., a desmid with small curved spines at the margin of the cell, all surrounded by a hyaline sheath, 500x.
- Illust. 14. Chlamydomonas sp., vegetative cells with pyrenoids, 750x.
- Illust. 15. Chlorella sp., ovoid cells with cup-shaped chloroplast, 1100x.
- Illust. 16. Closteriopsis longissima, portion of a filament showing pyrenoids along the cell wall, 126x.
- Illust. 17. Closterium sp., curved cell with two polar lobes, 875x.



## Illustrations 18-23

## Chlorophycophyta

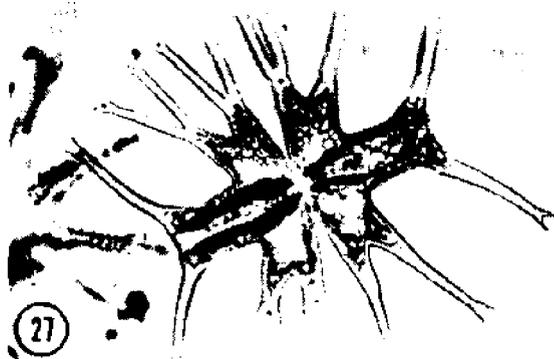
- Illust. 18-19 Coelastrum
- Illust. 18. Coelastrum sp., hollow sphere, notice the conical projections on the outer cells.
- Illust. 19. Coelastrum proboscideum, coenobium with cells united to form a hollow cube, 1500x.
- Illust. 20. Cosmarium sp., cell with a deep median constriction and rough cell wall, 1100x.
- Illust. 21. Desmidium sp., filament with indentations along the cell wall, 1250x.
- Illust. 22. Eudorina sp., colony with closely packed cells, flagella protruding from the matrix, 625x.
- Illust. 23. Eremosphaera viridis, large vegetative cell with cytoplasmic strands, 250x.



## Illustrations 24-29

## Chlorophycophyta

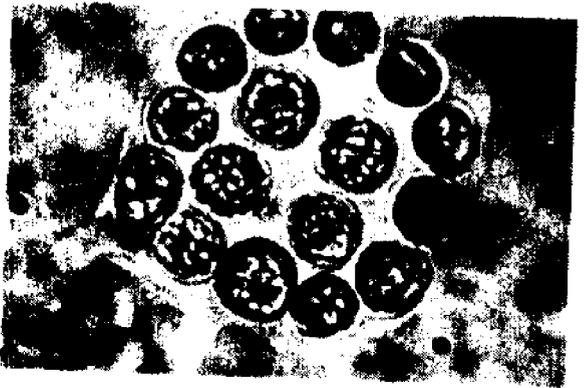
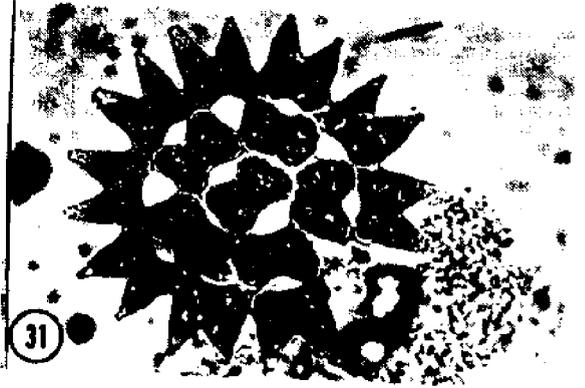
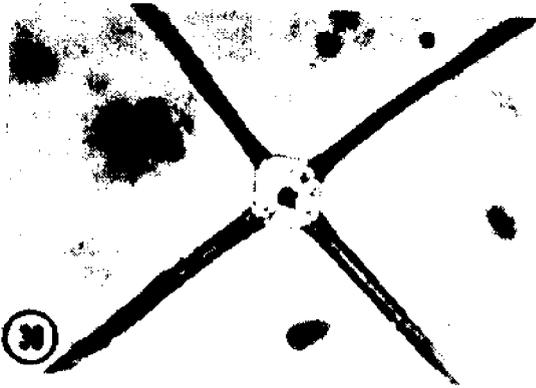
- Illust. 24. Euastrum sp., vegetative cell which contains four chloroplasts, 626x.
- Illust. 25. Hydrodictyon sp., immature nets, 435x.
- Illust. 26. Kirchneriella sp., colony with rounded sickle-shaped cells, 500x.
- Illust. 27. Micrasterias radiata, a desmid, bilaterally symmetrical, with projections radiating outward, 250x.
- Illust. 28-29 Oedogonium
- Illust. 28. Oedogonium sp., filaments with pyrenoids, 126x.
- Illust. 29. Oedogonium sp., filament showing storage products, 250x.



## Illustrations 30-35

## Chlorophycophyta

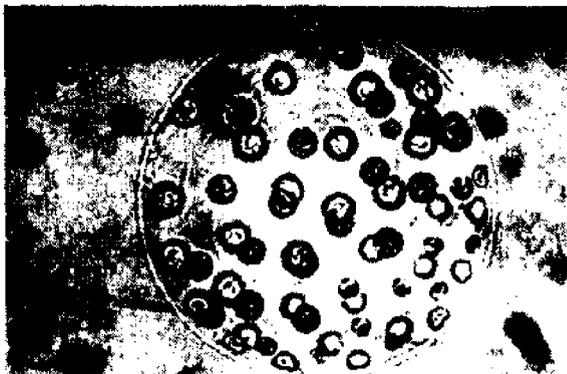
- Illust. 30. Pachycladon umbrinus, cell showing pyrenoid, which is often dark red, 875x.
- Illust. 31. Pediastrum sp., plate-like colony, 626x.
- Illust. 32. Pandorina morum, closely packed cells enclosed by a colonial matrix, 1000x.
- Illust. 33-34 Pithophora
- Illust. 33. Pithophora sp., filaments showing akinetes, 126x.
- Illust. 34. Pithophora sp., filaments with akinetes, notice the rhizoid-like processes on the filaments, 250x.
- Illust. 35. Platydorina caudata, colony of 16 cells with conical projections on the posterior end, 500x.



## Illustrations 36-41

## Chlorophycophyta

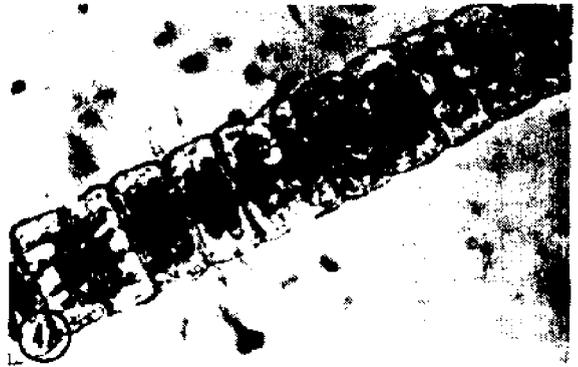
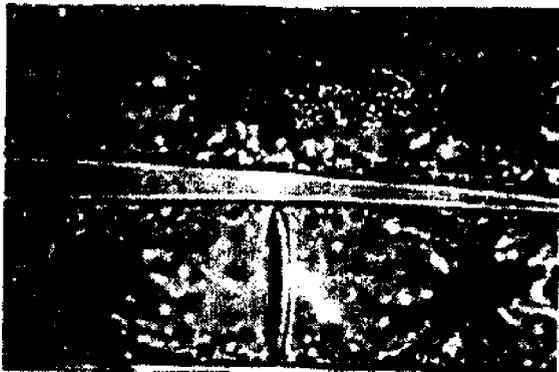
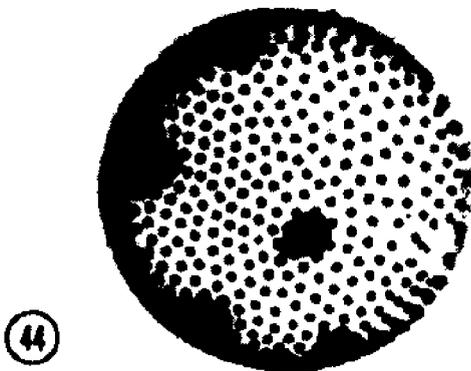
- Illust. 36. Pleodorina sp., colony showing the larger reproductive cells, 750x.
- Illust. 37. Scenedesmus sp., coenobium which has lost one cell, 1250x.
- Illust. 38. Spirogyra sp., vegetative filaments with tightly wound chloroplasts, 126x.
- Illust. 39-41 Staurastrum
- Illust. 39. Staurastrum sp., mature cell showing the two chloroplasts. This species occurred more often than other similar forms, 1200x.
- Illust. 40. Staurastrum sp., probably a zygote of Staurastrum. The cells are enclosed by a conspicuous sheath, 875x.
- Illust. 41. Staurastrum sp., rare form with spiny cell walls which occurred during the late spring and summer, 315x.



## Illustrations 42-47

## Chlorophycophyta

- Illust. 42. Tetraedron sp., common alga easily identified by the shape of the cell and the subdivided spines, 1250x.
- Illust. 43. Ulothrix sp., mat of filaments, 126x.
- Illust. 44. Volvox sp., typical colony with biflagellated cells, 189x.
- Illust. 45. Xanthidium sp., cell deeply constricted with two chloroplasts in each half, 500x.
- Illust. 46-47 Zygnema
- Illust. 46. Zygnema sp., mature filaments showing the two stellate chloroplasts, 500x.
- Illust. 47. Zygnema sp., filament forming storage products; not the same species as in Fig. 46, 500x.



## Illustrations 48-52

## Chlorophycophyta

- Illust. 48. Draparnaldia sp., portion of the thallus showing the prostrate and erect portions, 126x.
- Illust. 49. Netrium sp., large cell without a median constriction, 126x.
- Illust. 50. Pleurotaenium sp., large desmid with two polar lobes and slightly constricted at the midregion, 150x.
- Illust. 51. Penium sp., a desmid similar in appearance to Pleurotaenium (Illust. 50), but differs in that the apicies are rounded and without polar lobes, 126x.
- Illust. 52. Tetraspora sp., immature growth stage, notice that the majority of the cell lie in pairs, 126x.



ponds. The alga occurred sporadically during April and July in concentration ranging from 10 to 180 cells per liter.

Field identification.--None.

### Zygnema

Zygnema, Agardh, 1824 (Illust. 46, 47, p. 122 )

Description.--Filaments of Zygnema are long, thread-like and contain two stellate chloroplasts. The chloroplasts are linked to the cell wall by cytoplasmic extensions. The nucleus is centrally located between the chloroplasts.

Occurrence and significance.--Zygnema (Illust. 46) occurred intermingled with the filaments of Spirogyra during spring and winter months. Only vegetative filaments were encountered in the analyzed plankton samples. Cell counts usually ranged from 40 to 450 cells per liter.

Field identification.--None.

### Charophyta

In this division there are only three extant macroscopic genera, Chara, Nitella, and Tolypella, all of which are included in the class Charophyceae. Certain of these algae have the ability to complex calcium carbonate and become encrusted with calcium deposits. Hence, these

algae are often referred to as the stoneworts or brittleworts. The plants contain chlorophylls A and B, xanthophyles and carotenes; and store photosynthetic products as starch.

Development of the branched plant body is by apical growth of a single apical cell. The plant body is divided into nodes and internodes with whorls of leaves at the nodes. The leaves may be branched or entire.

Sexual reproduction is oogamous with antheridia (male organs) and oogonia (female organs) forming motile gametes and non-motile eggs respectively. Antheridia are covered by a row of crown cells. All sex organs are unicellular structures, surrounded by a sterile jacket.

Chara and Nitella are the most commonly occurring stoneworts. These algae are often unique to hatchery ponds in south Mississippi, but may occur in a variety of habitats including gravel pits, clear cold streams, or spring-fed ponds. They are particularly a nuisance in hatchery operations since dense growths frequently infest and cover the entire bottom of hatchery ponds. These growths interfere with hatchery feeding practices or prevent successful fish harvesting operations.

Since Chara and Nitella grow attached to the pond bottom and may grow to a length of several feet below the surface, they are difficult to control by ranking, cutting, or other mechanical means. The stoneworts may also be resistant to chemical control with copper sulfate, Diquat,

Karmex, Silvex, and sodium arsenite (Tatum et. al., 1962; Grizzwell, 1965; Cowell, 1965). However, Cutrine, a cheleated copper compound according to the manufacturer's label, will effectively control Chara. Normal application rates for Cutrine must be doubled for effective control. Cutrine is approved by the Environmental Protection Agency.

### Chara

Chara, Valliant, 1719 (Illust. 53, p. 131)

Description.--Chara may be distinguished from Nitella and other stoneworts by the presence of five crown cells on the oogonium. The plant body is divided into nodes and internodes with whorls of unbranched leaves occurring at the nodes. Chara complexes calcium carbonate from the water. The plant produces a skunk-like odor when crushed.

Occurrence and significance.--Chara occurred at Ole Joe's Hatchery, but did not occur at the Lyman hatchery. This alga occurred in three channel catfish fingerling ponds where it was considered a pest and subsequently eradicated. The ponds had differing amounts of Chara present and corresponding decreases in total phytoplankton with respect to the amount of Chara in the pond were noted. The greatest reduction in total phytoplankton occurred among the blue-green algae. Specific chemical, physical, and phytoplankton values have been discussed in a previous section.

Field identification.--Chara is a macroscopic plant often growing to a height of three feet, but usually does not grow above the water surface. Unlike filamentous algae, this alga grows attached to pond muds and does not form floating mats.

The plant may be identified by the skunk-like odor and the red and black reproductive organs.

### Nitella

Nitella, Agardh, 1824 (Illust. 54, p. 133)

Description.--Nitella differs from Chara in that it does not complex calcium carbonate. The plant body and branches are divided into nodes and internodes with whorls of branched leaves occurring at the nodes. Ten crown cells were present on the oogonium.

Occurrence and significance.--Nitella (Illust. 54) occurred in a channel catfish fingerling pond at Ole Joe's Hatchery during January, February, and March. The alga covered approximately 50 percent of the bottom and prevented the pond from being used to full capacity. The pond was drained during April, 1972, to eradicate the Nitella.

Phytoplankton diversity was greater in the Nitella-filled pond than in adjacent ponds. The algal flora consisted only of green algae, diatoms, dinoflagellates,

and Euglenoids. Volvox sp. (Illust. 44) was the dominant green algae while Fragilaria (Illust. 57) was the dominant diatom. Cell counts for Volvox usually ranged from 350 to 1,200 cells per liter.

Field identification.--Superficially Nitella resembles Chara but may be differentiated by the lack of calcium carbonate deposits and the absence of a skunk-like odor.

#### Chrysophycophyta

The Chrysophycophyta are a unique group of organisms with the majority of the genera having cell walls which contain silica and are composed of two overlapping halves (H-shaped pieces). This division is divided into three classes--Xanthophyceae, Chrysophyceae, Bacillariophyceae. All members of this division have the pigments localized in the chromatophores. Chlorophylls A and C as well as xanthophyll and carotene pigments are present. Xanthophylls and carotenes mask the chlorophylls giving these organisms a distinctive yellow-green or golden brown color. Photosynthetic products are stored as oil or as leucosin.

The majority of the Chrysophycophyta are microscopic. Certain species may be unicellular, colonial, filamentous, branched, or siphonaceous. In addition, the yellow-green algae may be motile or non-motile. Many motile forms move by means of two flagella which are unequal in length.

Illustration 53

Charophyta

Illust. 53. Chara sp., sketch showing the branched plant body, reproductive structures, and calcium deposits. The branchlets of the plant are unbranched.

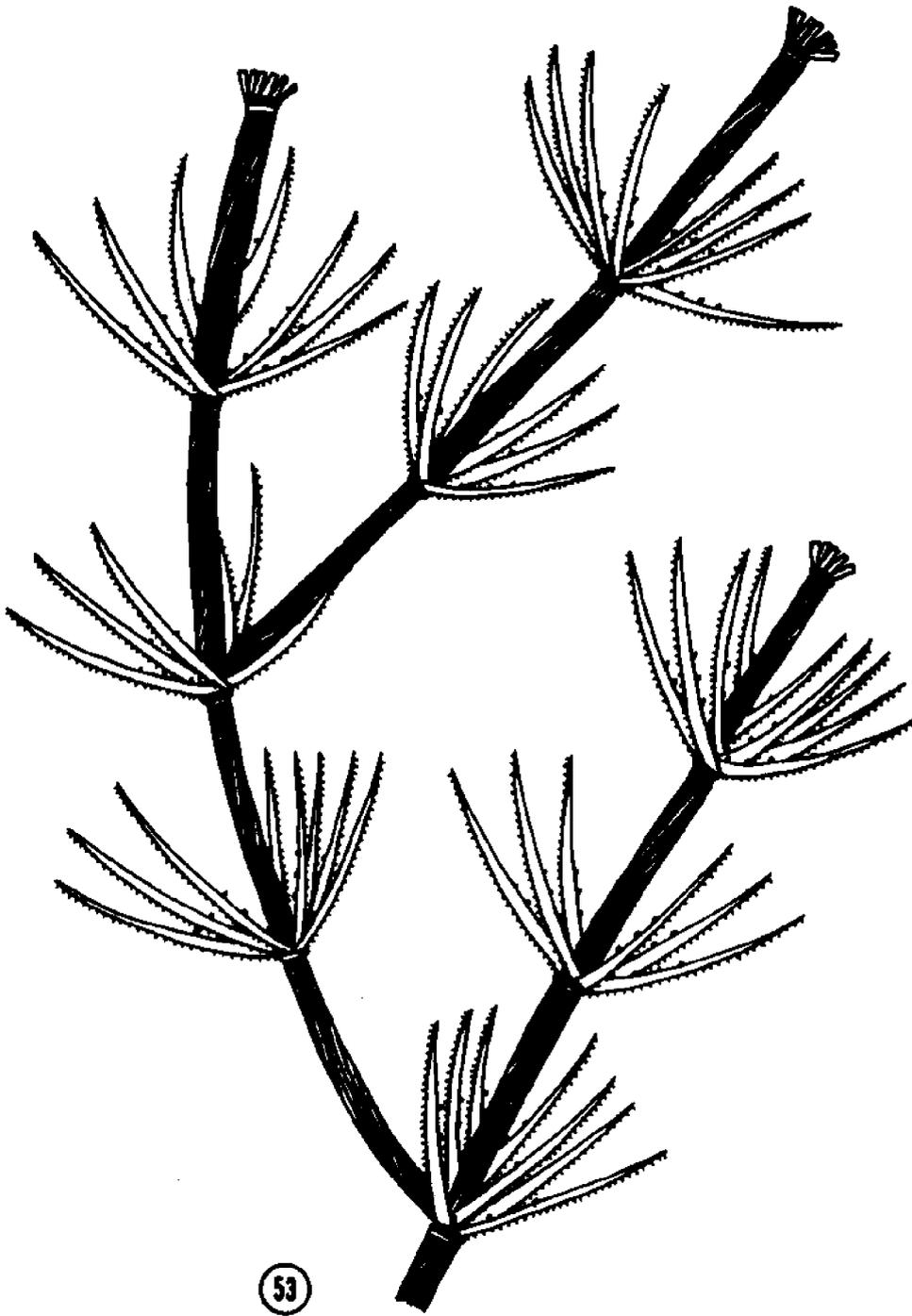
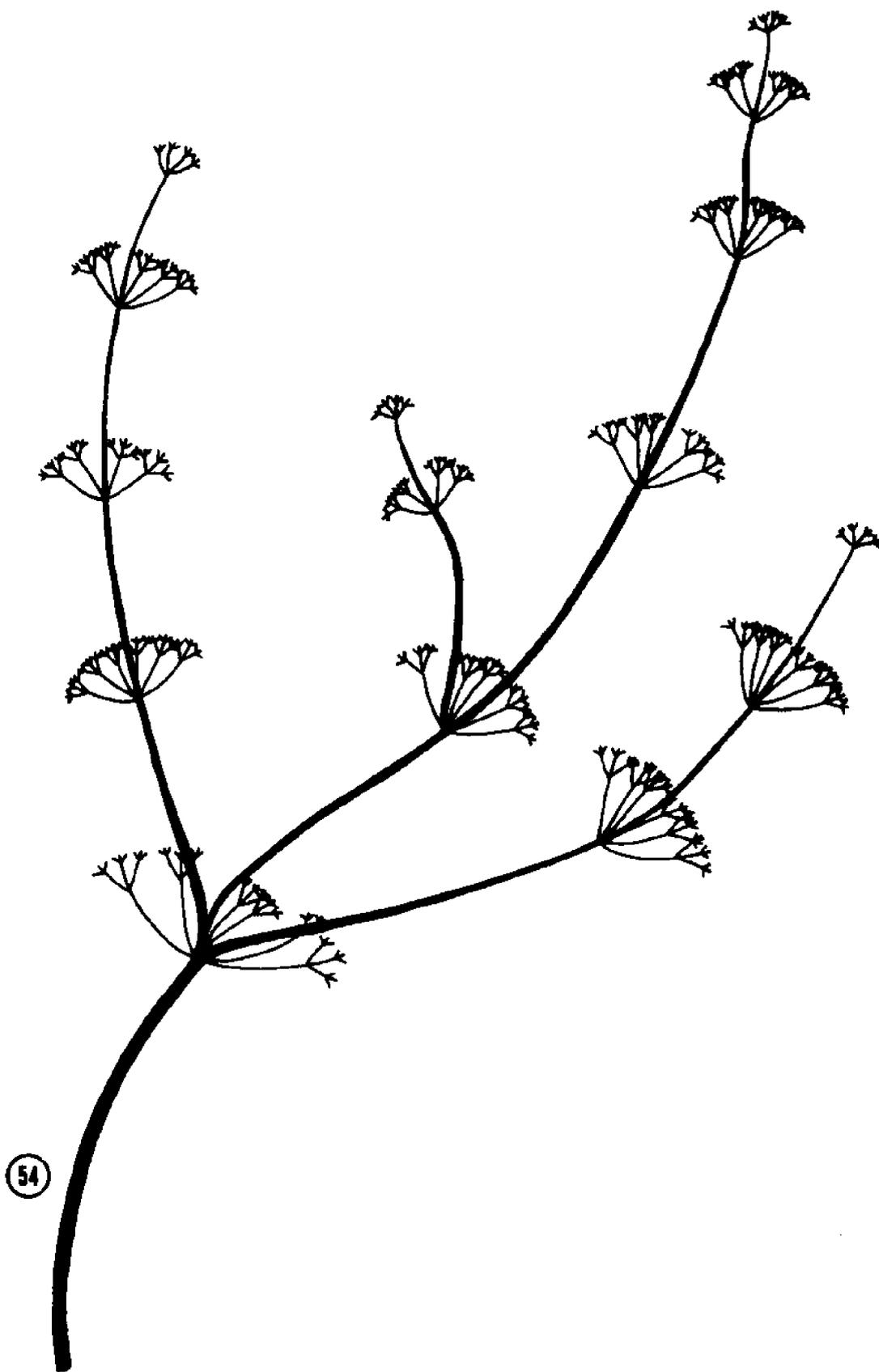


Illustration 54

Charophyta

- llust. 54. Nitella sp., sketch showing the branchlets of which all are branched.



54

Certain members of the Chrysophycophyta have green algal counterparts, i.e., morphologically similar algae such as Botrydium and Protosiphon which are classified in two separate divisions. Many yellow-green algae are parallel with green algae in other respects to include both sexual and asexual reproduction.

In all probability, the most significant group of algae are the diatoms--class Bacillariophyceae. These organisms occur in fresh water and marine habitats. Diatoms, as well as other algae found in the marine environment produce the majority of all photosynthetic carbon on earth, according to some authorities. In the marine environment diatom frustules (cell walls) have formed massive deposits of diatomaceous earth. These deposits have several industrial uses, and are mined on a commercial basis.

#### Significance of Yellow-Green Algae in Hatchery Ponds

The yellow-green algae are not normally considered nuisance organisms in hatchery ponds. In fact, many authorities consider the yellow-green algae a basic component of the aquatic food chain (Bold, 1967). Although the yellow-green algae are usually considered taste and odor producers, many have the ability to produce profuse blooms (Palmer, 1959; Hutchinson, 1944). A few typical examples of bloom producing yellow-green algae are:

Fragilaria, Navicula, Asterionella, Dinobyron, and Synura (Illust. 55-59 and 61-62).

Fortunately many yellow-green algae are very susceptible to copper sulfate. Bartsch (1954) recommended 0.9 pound copper sulfate per surface acre for waters with the methyl orange alkalinity below 50 mg/l. For waters above 50 mg/l, 5.4 pounds copper sulfate are recommended. For hard waters citric acid may be added at a rate of 30 to 50 percent citric acid of the copper sulfate used (Snow et al., 1964). This mixture prevents the copper sulfate from precipitating as copper carbonate.

#### Asterionella

Asterionella, Hassall, 1850 (Illust. 55, p. 142)

Description.--Asterionella is a free-floating stellate colony with the cells joined by gelatinous secretions. Joined ends of the cell are larger than free ends. A pseudopod is present in individual cells while internal separation is absent. Two chromatophores are present in each cell.

Occurrence and significance.--Asterionella (Illust. 55) occurred during May, June, and July in concentrations ranging from 20 to 300 cells per liter. The alga was present on two additional sampling dates in September and March. Total cell counts for Asterionella indicate that the organism did not reach bloom proportions throughout the year.

Field Identification.--None.

Dinobyron

Dinobyron, Ehrenberg, 1835 (Illust. 56, p. 142)

Description.--Dinobyron is a free-swimming colonial alga common in lakes and ponds. The branching colonies are composed of bell-like loricas which surround the cell. Two flagella of unequal length extend from the lorica. The loricas are usually colorless, or occasionally brown.

Occurrence and significance.--Dinobyron (Illust. 56) occurred frequently at Ole Joe's Hatchery and was intermingled with blooms of Ceratium and Peridinium (Illust. 67, 68).

Cell counts at Ole Joe's ranged from 4,000 to 6,000 cells per liter during May. Cell counts at the Lyman Hatchery ranged from 20 to 90 cells per liter during December, January, February, and March.

Field identification.--None.

Fragilaria

Fragilaria, Lyngbye, 1819 (Illust. 57, p. 142)

Description.--The cells of Fragilaria may be united to form band-like colonies, zig-zag colonies, or may occur as single cells. Colonies as well as single cells may be

free-floating or attached. Individual cells are inflated at the mid region and lack longitudinal septation.

Occurrence and significance.--Fragilaria (Illust. 57) was the most abundant diatom at the two hatcheries. The alga was present throughout the year and occurred primarily in channel catfish rearing ponds. Ponds that were muddy had higher diatom counts. Single cells of Fragilaria were encountered more often than colonies or chains. The highest recorded count for Fragilaria was 16,056 cells per liter on July 22, 1971. Otherwise, cell counts for Fragilaria remained fairly constant (40 to 4,000 cells per liter) from month to month.

#### Mallomonas

Mallomonas, Perty, 1852 (Illust. 58, p. 142)

Description.--Mallomonas is a unicellular organism motile by means of one flagellum. The cells may be oval, cylindrical, or variously shaped. Numerous armor-like plates cover the cell wall. Spines protrude from the plates and may cover the entire cell or only the terminal end.

Occurrence and significance.--Mallomonas (Illust. 58) occurred during January, March, and May in concentrations ranging from 30 to 720 cells per liter. The organism occurred intermingled with blooms of Ceratium, Peridinium,

or Dinobyron and usually constituted from one percent to four percent of the total plankton.

Field identification.--None.

### Navicula

Navicula, Bory, 1822 (Illust. 59, p. 142 )

Description.--Navicula is a free-floating pennate diatom with the cells occurring solitarily or in clusters. The cells have a narrow distinct raphe and are slightly rounded at the poles. Transverse striations extend from the outer cell wall toward the raphe.

Occurrence and significance.--Navicula (Illust. 59) occurred during spring, summer, and fall, but occurred only once during the winter. A dense concentration (320,760 cells per liter) occurred at Lyman Hatchery on July 2, 1971. Navicula, like Fragilaria and other diatoms, occurred primarily in channel catfish rearing ponds. The alga only occurred on two sampling dates at Ole Joe's Hatchery in concentrations ranging from 20 to 100 cells per liter. Total counts indicate that this alga may occasionally require chemical treatment.

### Surirella

Surirella, Turpin, 1828 (Illust 60, p. 142)

Description.--Surirella is an oval shaped diatom with one pole larger than the other. Transverse costae

on the cell wall are parallel and occur in a long-short pattern. These striations are interrupted by an inconspicuous pseudoraphe.

Occurrence and significance.--Surirella occurred primarily during December, January, February, and March and never constituted over one percent of the total plankton.

Field identification.--None.

### Synura

Synura, Ehrenberg, 1838 (Illust. 61, 62, p. 144)

Description.--The cells are united to form free swimming spherical, oblong, or ovoid colonies. Two flagella unequal in length are present on each cell. Spine-bearing scales cover the entire cell.

Occurrence and significance.--Synura (Illust. 61) occurred in small concentrations consisting of 40 to 180 cells per liter. The alga usually composed from 1 percent to four percent of the total plankton.

Field identification.--Small concentrations of Synura, if present in contained water (plankton samples), produced a pronounced canteloupe-like odor.

Tabellaria

Tabellaria, Ehrenberg, 1840 (Illust. 63, 64, p.

Description.--Tabellaria may occur in straight, band-like or zig-zag chains; and occasionally occurs in stellate colonies. The cells are tabular in girdle view and have longitudinal septa which are interrupted near the center of the cell. Transverse septa extend across the cell wall and are interrupted by the pseudopores.

Occurrence and significance. --Tabellaria (Illust. 63) occurred on one sampling date during April, 1971, and constituted only one percent of the total plankton.

Plankton analysis of ponds at Ole Joe's Hatchery and the Lyman Hatchery indicated that Tabellaria was not a bloom causer. However, the organism did reach bloom proportions in several ponds near Hattiesburg and the surrounding area. In these ponds the alga was frequently present in dense concentrations.

Tribonema

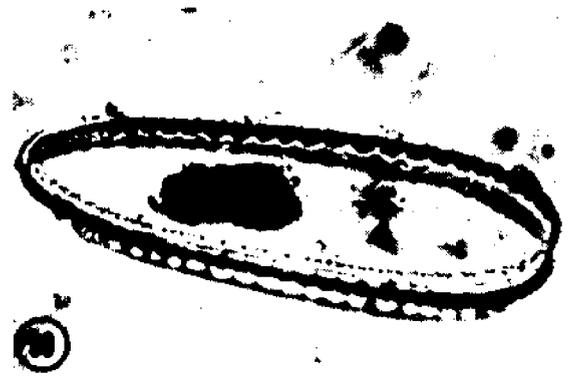
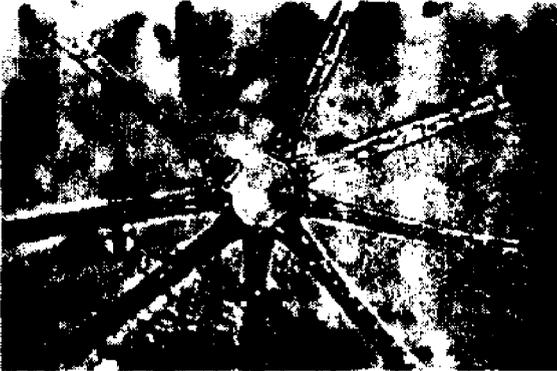
Tribonema, Derbes and Solier, 1856 (Illust. 65, 66, p. 144)

Description.--The cells are cylindrical and round with the cell wall composed of overlapping H-shaped pieces. Numerous chromatophores occur unevenly distributed throughout the cell or may occur in a parietal position along the cell wall.

## Illustration 55-60

## Chrysophycophyta

- Illust. 55. Asterionella sp., stellate colony, which has lost one cell, 500x.
- Illust. 56. Dinobryon sp., colony with bell-shaped loricas, 250x.
- Illust. 57. Fragilaria sp., single cell inflated at the midregion, 600x.
- Illust. 58. Mallomonas sp., cell with armor-like plates bearing spines, 500x.
- Illust. 59. Navicula sp., clump of cells joined by gelatinous secretions, 625x.
- Illust. 60. Surirella sp., oval-shaped cell inflated at one end (valve view), 500x.



## Illustrations 61-66

## Chrysophycophyta

Illust. 61-62 Synura

Illust. 61. Synura uvella, colony of biflagel-  
lated cells, each covered by  
scales, 400x.

Illust. 62. Synura sp., oblong colony, 780x.

Illust. 63-64 Tabellaria

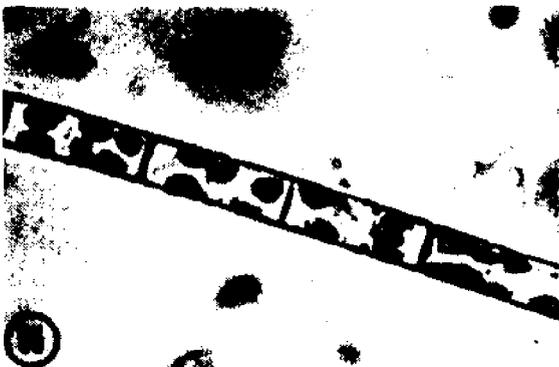
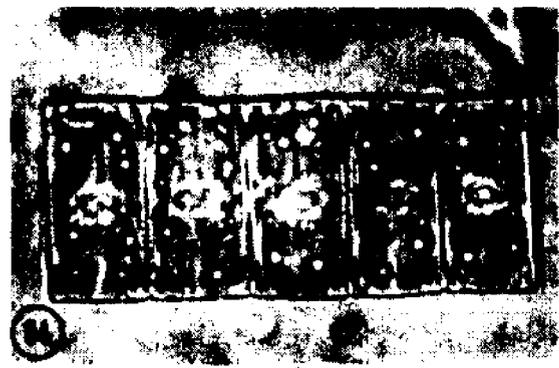
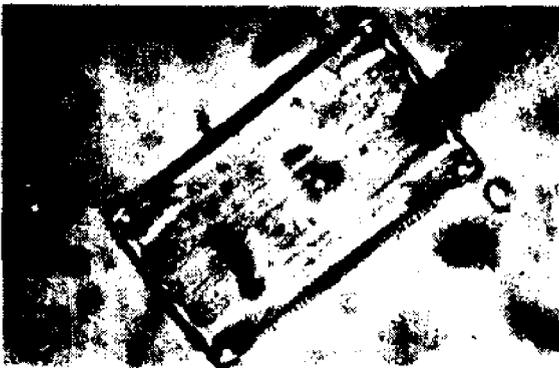
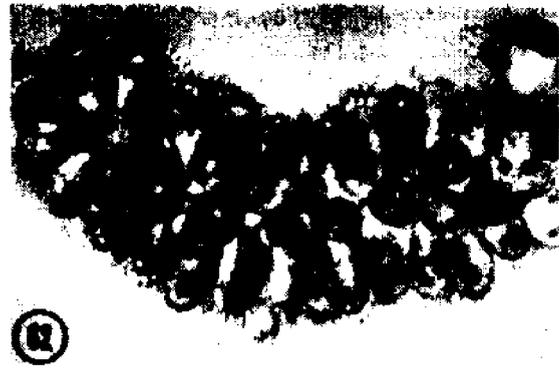
Illust. 63. Tabellaria sp., filaments  
united to form a plate-like  
colony, 250x.

Illust. 64. Tabellaria sp., colony; not  
the same species as in  
Illust. 59, 500x.

Illust. 65-66 Tribonema

Illust. 65. Tribonema sp., filament showing  
the unevenly distributed chroma-  
tophores, 780x.

Illust. 66. Tribonema sp., mat of barrel-  
shaped filaments, 500x.



Occurrence and significance.--Tribonema was a major bloom causer in hatchery ponds. Dense concentrations occurred during fall where the alga constituted 88 percent of the total plankton. Tribonema constituted only one to four percent of the plankton during June and July. Cell counts for Tribonema ranged from 20 to 4,000 cells per liter during summer and from 300 to 7,000 cells per liter during fall.

Field identification.--None.

#### Pyrrhophycophyta

The dinoflagellates contain both chlorophyll-bearing and colorless organisms. They are primarily marine in habitat; but a few species also occur in fresh water. The pigments are localized in yellow-green to golden brown chromatophores. The chromatophores contain chlorophylls A and C, beta-carotene, and four xanthophylls. A large conspicuous nucleus is present with the chromatin material within the nucleus occurring in thread-like beads. Photosynthetic products are stored as starch or as oil.

Sexual reproduction has been reported for some species. However, asexual reproduction predominates and is by cell division, zoospores, daughter cells, or cyst formation.

The cell wall is composed of cellulose and consists of two over-lapping halves commonly known as the epitheca and the hypotheca. Armor-like plates are present on the cell wall and serve as a basis for morphological separation. A centrally-located spiral groove with two laterally attached flagella is present in many dinoflagellates.

#### Dinoflagellate Blooms

The dinoflagellates are capable of producing dense blooms in marine and fresh water environments. In the marine environment, Gymnodinium brevis, Gonyaulax sp. and other dinoflagellates may produce dense blooms which are commonly known as the Red Tide. These organisms, when present in large numbers, produce lethal toxins that accumulate in shellfish and later cause massive fish mortality (Schantz, 1971). Certain species of Peridinium and Gymnodinium that occur in fresh water lakes and ponds have been reported to produce toxins.

Ceratium and Peridinium (Illust. 67, 68) are primarily fresh water organisms that are frequently found in abundance. These algae are usually considered taste and odor producers and if present in abundance may require chemical control (Palmer, 1959). Chemical control for Ceratium and Peridinium can be accomplished with copper sulfate. Applications rates for copper sulfate are discussed.

Ceratium

Ceratium, Schrank, 1793 (Illust. 67, p. 149)

Description.--Ceratium may be identified by the presence of one long anterior horn and two to three posterior horns. The cells are symmetrically shaped and are motile by means of two flagella. The flagella are located in a central spiral-like groove that is interrupted by a conspicuous vertical plate. Armor-like scales cover the cell wall.

Occurrence and significance.--Ceratium (Illust. 67) was present in dense concentrations (15,000 cells per liter) during May, 1971, at Ole Joe's Hatchery, but did not occur in abundance throughout the summer. The alga reoccurred in abundance during September and reached maximum fall concentrations (500 to 9,000 cells per liter) during November. Cell counts for Ceratium during January and February ranged from 1,000 to 3,000 cells per liter.

Field identification.--Pond water containing dense concentrations of Ceratium is colored yellow-brown to dark brown and has a characteristic oily or slick touch sensation. The water has a pronounced fishy taste. In addition, plankton nets have an oily or slick touch sensation after towing. The plankton net is usually colored yellow-brown or dark brown.

## Illustration 67-68

## Pyrrhophycophyta

- Illust. 67. Ceratium hirundinella, mature cell showing the anterior and posterior horns, 250x.
- Illust. 68. Peridinium sp., cell with spiral groove and armored plates, 626x.



Peridinium

Peridinium, Ehrenberg, 1830 (Illust. 68, p. 149)

Description.--Peridinium is a solitary free swimming organism motile by means of two flagella. The cells may be oval or angular in shape with spine-like processes occurring on the posterior end. The cell is composed of an epitheca and a hypotheca. A spiral groove is centrally located and contains the flagella. Horn-like processes may occur on the anterior and posterior portions of the cell. The cell wall is also covered by armor-like plates.

Occurrence and significance.--Peridinium (Illust. 68) usually occurred intermingled with blooms of Ceratium, and constituted from one to four percent of the total plankton. Maximum concentrations of Peridinium consisting of 300 to 3,000 cells per liter occurred during September and October.

Field identification.--Identical with Ceratium.

Euglenophycophyta

The euglenoids contain chlorophylls A and B as well as xanthophyll and carotene pigments. The division is characterized by the absence of a definite cell wall. The outer covering (periplast) may be rigid or exhibit metaboly i.e., euglenoids frequently contract or change shape. These

algae are obligate B<sub>12</sub> requirers and to this extent are heterotropic organisms which store all food reserves including photosynthetic products as a starch-like compound called paramylin.

The cells are motile by one tensile-like flagellum and contain a light-sensitive red eyespot.

Sexual reproduction is of rare occurrence. Reproduction is usually accomplished by cell division or other vegetative means.

### Euglena

Euglena, Ehrenberg, 1828 (Illust. 69, p. 153)

Description.--Euglena is a free-swimming organism motile by means of one tensile-like flagellum. The outer covering of the cell is not rigid. Therefore, Euglenas can frequently be observed contracting or changing shape. The cells contain a red eyespot as well as discord chromatophores. The chromatophores are often obscured by the paramylin granules.

Occurrence and significance.--Euglena was one of the rarest algae that occurred at the two hatcheries. This alga usually constituted less than one percent of the total plankton.

Field identification.--In ponds where dense concentrations of Euglena occur, a red film-like covering is usually present (Prescott, 1968).

## Illustrations 69-72

## Euglenophycophyta

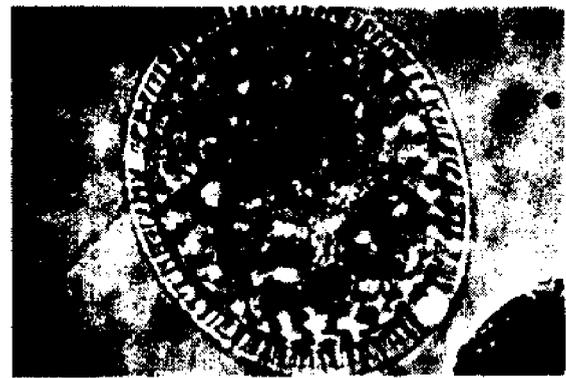
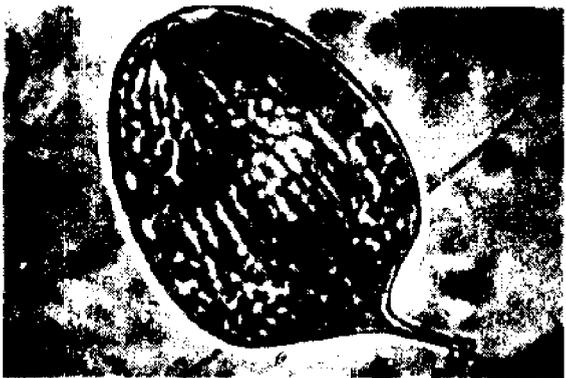
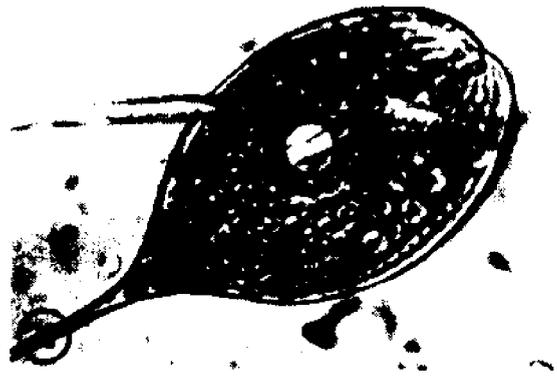
Illust. 69. Euglena sp., cell exhibiting metaboly. The red eye spot is located at the anterior end of the cell, 525x.

Illust. 70-72 Phacus

Illust. 70. Phacus sp., large cell with transverse striations, 625x.

Illust. 71. Phacus sp., short-horned type with concentric rings at the center, 625x.

Illust. 72. Phacus sp., encysted cell, 625x.



Phacus

Phacus, Dujarden, 1841 (Illust. 70-72, p. 153)

Description.--The cells are typically flat with longitudinal striations occurring on the periplast. The periplast is rigid with a spine-like process occurring at the posterior end. A red eyespot, paramylin granules, and discoid chromatophores are present within the cells.

Occurrence and significance.--Phacus occurred in a combined total of five ponds on eight sampling dates. The alga never constituted over one to four percent of the total plankton.

Field identification.--None.

## CHAPTER V

### CHEMICAL CONTROL OF THE ALGAE

In commercial fish culture fertilization with fish foods, organic fertilizers, and by agricultural drainage creates an artificial eutrophic environment, which encourages nuisance growths of algae. Under these conditions both filamentous and planktonic algae frequently produce obnoxious growths that often reduce total fish production through oxygen depletion. Biological control with herbivorous fish, and mechanical control by raking or cutting, although effective on a small scale, are not feasible or economical in many cases. Therefore, in ponds where the algae produce blooms or form dense floating mats year after year, the control of the organisms by chemical means is often the most economical and permanent method.

The chemical control of algae consists of the application of a specific herbicide that will control the nuisance algae. The nuisance algae must be identified and the most effective agent applied at the lowest possible rate for adequate control. Further, the application of the herbicide requires careful planning in order to avoid levels that are toxic to fish and fish food organisms.

Normally, a herbicide that controls the pest algae and is low in cost and toxicity to fish and other animals is used.

This section includes the general characteristics and chemical composition of several herbicides. The applications rates listed for each herbicide are those determined by field evaluation, bioassay, or the manufacturer's recommendations.

Casoron, 2,6-dichlorobenzonitrile, is an aquatic herbicide used primarily for the control of aquatic weeds and filamentous algae. Casoron, will effectively control Pithophora at a rate of 2mg/l active ingredient (Dow Chemical Company). The granular form of the herbicide is less toxic to fish than the powder form (Hughes and Davis, 1962).

Casoron AQ (10 percent granular form) is available in fifty pound bags at a cost of approximately ninety-four cents per pound.

Copper sulfate,  $\text{CuSO}_4$ , is approved for use at all commercial and federal hatcheries. The algaecide is relatively inexpensive (\$33.50 per 100 pound bag) and is available in powder, snow, or crystalline form. Copper sulfate is a non-selective algaecide that effectively controls a number of algae. Several algae that are effectively controlled by copper sulfate are listed in

Table 16. The recommended application rate for waters with less than 25 mg/l total hardness is 0.75 pound per surface acre (Crance, 1963; Snow, 1956).

Cutrine, is a chelated copper compound that effectively controls filamentous, planktonic, and attached algae in hard or soft waters. The chemical is relatively non-toxic to fish and other animals if recommended application rates are followed. It is more expensive than copper sulfate (\$14.00 to \$16.00 per gallon) but unlike copper sulfate, Cutrine will control Chara and Nitella. The amount needed for one application can be calculated from the following formula: total surface area to be treated times average depth times  $3/4$  = number of gallons needed. Application rates must be doubled for Chara. Cutrine is approved by the Environmental Protection Agency.

Delrad, dehydroabietylamine acetate, is a contact algaecide which, according to Lawrence (1954) and Johnson (1955), will effectively control Pithophora and Ulothrix at a rate of 0.25-0.55 mg/l Delrad active ingredient per surface acre. Johnson (1955) also stated that laboratory investigations indicated that Delrad would effectively control Spirogyra and Oscillatoria. The algaecide is toxic to bluegills, goldfish, and largemouth bass fry at concentrations of 0.7 mg/l and should not be used in brood ponds (Lawrence, 1954).

TABLE 16  
ALGAE CONTROLLED BY COPPER SULFATE

		Illust. No.
Blue-green	<u>Anabaena</u>	1
	<u>Aphanizomenon</u>	3
	<u>Polycystis</u>	8
	<u>Oscillatoria</u>	7
Green	<u>Coelastrum</u>	18
	<u>Closterium</u>	17
	<u>Hydrodictyon</u>	25
	<u>Spirogyra</u>	38
	<u>Ulothrix</u>	43
	<u>Volvox</u>	44
	<u>Zygnema</u>	46
Yellow-green	<u>Asterionella</u>	55
	<u>Dinobryon</u>	56
	<u>Fragilaria</u>	57
	<u>Mallomonas</u>	58
	<u>Synura</u>	61
	<u>Tabellaria</u>	63
Dinoflagellates	<u>Ceratium</u>	67
Euglenoids	<u>Euglena</u>	69

Dichlone, 2,3-dichloro-1,4-naphthoquinone, is a contact algaecide used primarily for the control of blue-green algae. Fitzgerald and Skoog (1954) reported that Dichlone controlled blooms of Microcystis, Aphanizomenon, and Anabaena at concentrations of 20 to 55 parts per billion and was not toxic to fish. However, Lawrence (1958) stated that the algaecide was toxic to fish at concentrations of 0.05 to 0.1 mg/l.

Diquat, 1:1 ethylene-2:2-bipyridylum cation (salt) is a non-selective herbicide that has been used to effectively control Hydrodictyon, Spirogyra, and several other filamentous algae at application rates ranging from 0.2-0.3 mg/l diquat cation (Lawrence *et al.*, 1962). The herbicide is relatively non-toxic to fish, but significant reductions in total phytoplankton may occur (Tatum and Blackburn, 1962). Commercial formulations of diquat are available at approximately \$35.75 per gallon.

Karmex, 3-(3,4-dichlorophenyl)-1,1-dimethylurea is an aquatic herbicide which, according to Sills (1964), will effectively control Spirogyra, Cladophora, Oedogonium, and Pithophora at a rate of one-half pound per surface acre. The herbicide is relatively non-toxic to fish and zooplankton but causes substantial reductions in total phytoplankton (Grizzell, 1965). The herbicide costs approximately \$2.65 per pound.

Paraquat, 1:1 dimethyl-4:4 bipyridylium cation (salt) is an effective agent for the control of primarily filamentous algae. This formulation is chemically similar to Diquat, but is toxic to fish at 0.5 mg/l whereas Diquat is toxic at 0.1 mg/l (Lawrence *et al.*, 1962). Paraquat, in many cases, is an effective control for algae. However, the herbicide costs approximately \$30.00 per gallon which prevents its widespread use.

Silvex, 2-(2,4,5, trichlorophenoxy) propionic acid is an aquatic herbicide used primarily for broad leaf plants. Cowell (1965) reported that 2 mg/l Silvex controlled Hydrodictyon and Spirogyra but did not control Chara. A commercial formulation labeled Aquathol which contains 22.1 percent Endothall dipotassium salt plus 25.3 percent Silvex dipotassium salt is available at \$13.50 per gallon.

S-Triazines, Simazine (2-chloro-4, 6-bis (ethylamino)-s-triazine) atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) and prometryne (2,4-bis (isopropylamino)-6-methylthio-s-triazine) as reported by Pierce *et al.* (1964) will effectively control all filamentous algae. Snow (1963; 1964) stated that Simazine at a rate of 2-3 mg/l effectively controlled Pithophora, Hydrodictyon, Anabaena, and Zygnema. Simazine is non-toxic to zooplankton, but causes significant reductions in total phytoplankton (Snow, 1964).

Sodium arsenite,  $\text{Na}_2\text{As}_2\text{O}_3$  is an inorganic arsenic compound moderately toxic to fish and fish food organisms

(Snow, 1964). This herbicide is used as a control for filamentous algae and aquatic weeds. According to Cowell (1965) sodium arsenite at a rate of 4 mg/l will control Cladophora, Spirogyra, Zygnema, and Potamogeton, but did not control Chara. Phytoplankton was not reduced but the arsenic was absorbed by the algae which may later reduce zooplankton (Cowell, 1965).

## CHAPTER VI

### SUMMARY AND CONCLUSIONS

The seasonal variation, periodicity, and relative abundance of six divisions of the algae occurring at a commercial and a federal fish hatchery were investigated every two weeks from April, 1971 through May, 1972. Chemical and physical factors, which include dissolved oxygen, pH, hardness, temperature, phosphorus, and nitrogen were correlated with phytoplankton production, periodicity, and seasonal variation.

A temperature differential of 4° to 5°C between the hatcheries did not reflect any major differences in phytoplankton diversity, although phytoplankton periodicity was directly related to temperature.

Suboptimal dissolved oxygen concentrations, which were recorded occasionally at both hatcheries were caused by the decomposition of phytoplankton blooms or mats. Alkaline pH values and high hardness values for selected ponds at both hatcheries were correlated with the occurrence of several filamentous algae and desmids.

Minimum orthophosphate values (0.015 mg/l) corresponded with maximum phytoplankton values; whereas, high

polyphosphate values correlated with maximum phytoplankton values. Neither phosphorus nor nitrogen accounted for the periodicity or diversity of the algae. However, nitrogen values did correlate with phytoplankton production more closely than phosphorus values.

The majority of the phytoplankton found at the hatcheries consisted of green algae with diatoms and other chrysophytes, usually the co-dominant algae. Ankistrodesmus, Closteriopsis, Chlorella, Navicula, Fragilaria, and Tribonema were the principal green and yellow-green algae found in bloom proportions. Members of the Cyanophycophyta were encountered throughout the year, but usually reached maximum concentrations during the spring, summer, and fall. Ceratium and Peridinium members of the Pyrrophytophyta were consistently minor components of the plankton at the federal hatchery, but were bloom producers at the commercial hatchery during the spring and fall. Euglenoids were minor components of the plankton at both hatcheries.

Three Chara-filled ponds were investigated at the commercial hatchery and revealed that total phytoplankton followed decreasing coverage by Chara. Chemical and physical factors for the three ponds were adequate for an algal bloom. The reduction of total phytoplankton in the plant-filled ponds as compared with adjacent ponds was attributed to a growth limiting substance released by the Chara.

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